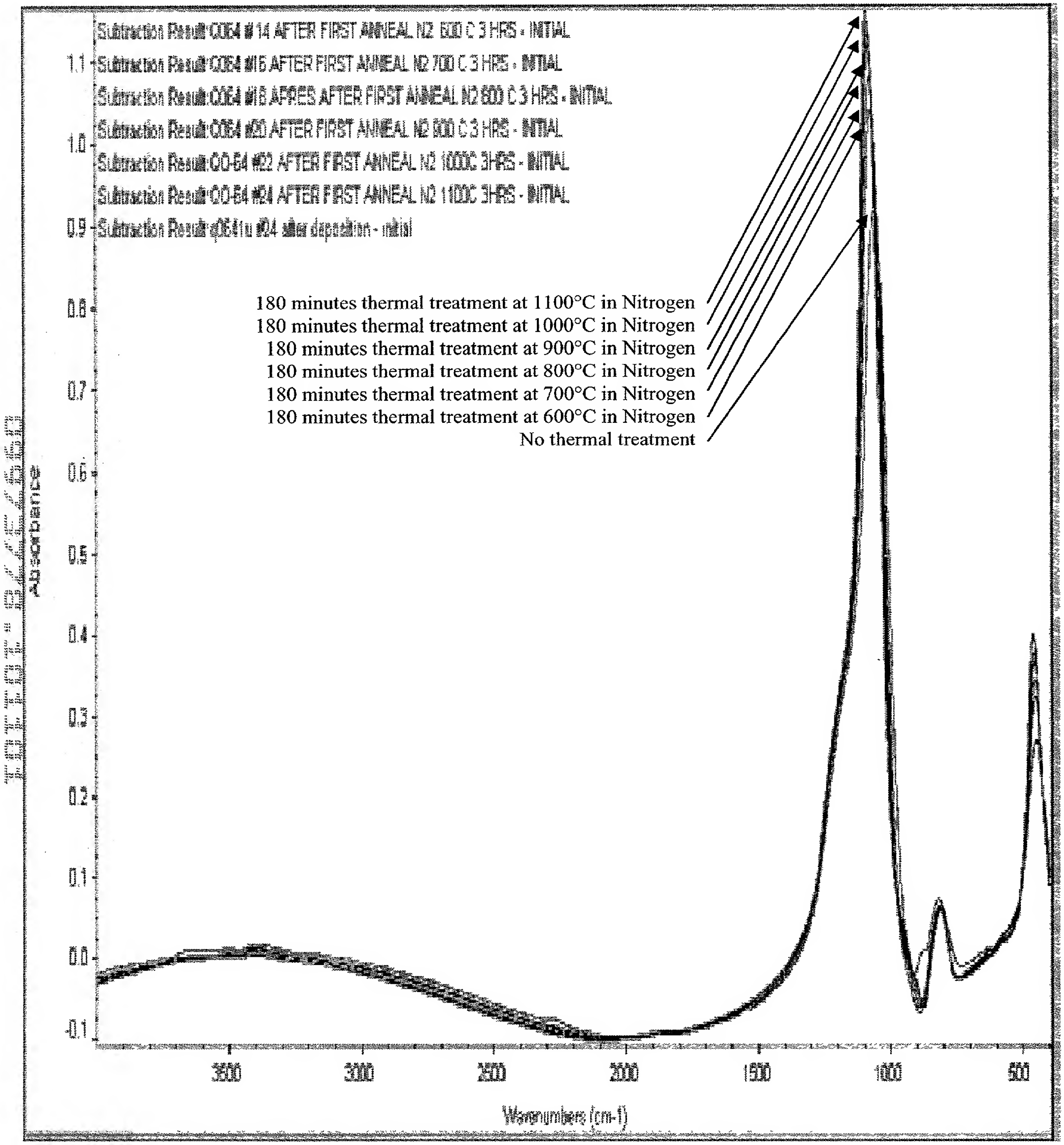
Figure 1

Publication	PECVD Reaction	'Delta-n' Control Method	Post-dep. Thermal Treatment T° (°C)
Valette S.,1987	Unknown	P doping	Not specified
Valette S.,1988	**Unknown**	**P doping**	**400°C**
Grand G., 1990	Unknown	P doping	1000°C
Liu K., 1995	Unknown	Content in Si, P	Not specified
Ojha S., 1998	Unknown	Ge, B, or P doping	Not specified
Canning J., 1998	Unknown	Ge doping	Not specified
Bulla D., 1998	TEOS	TEOS	Not specified
Johnson C., 1998	**$SiH_4 + O_2$**	**Si ion Implantation**	**400°C**
Boswell R. W., 1997	$SiH_4 + O_2$	SiH_4/O_2 flow ratio	1000°C
Bazylenko M. V., 1995	$SiH_4 + O_2 + CF_4$	$(SiH_4+O_2)/CF_4$ flow ratio	Not specified
Bazylenko M. V., 1996	$SiH_4 + O_2 + CF_4$	$(SiH_4+O_2)/CF_4$ flow ratio	1000°C
Durandet A., 1996	**$SiH_4 + O_2 + CF_4$**	**$SiH_4/O_2/CF_4$ flow ratio**	**100°C**
Kapser K., 1991	$SiH_4 + N_2O$	SiH_4/N_2O flow ratio	1060°C
Lai Q., 1992	$SiH_4 + N_2O$	SiH_4/N_2O flow ratio	1100°C
Lai Q.,1993	$SiH_4 + N_2O$	SiH_4/N_2O flow ratio	1100°C
Pereyra I., 1997	**$SiH_4 + N_2O$**	**SiH_4/N_2O flow ratio**	**400°C**
Alayo M., 1998	$SiH_4 + N_2O$	SiH_4/N_2O flow ratio	1000°C
Kenyon T., 1997	$SiH_4 + N_2O + Ar$	$SiH_4/N_2O/Ar$ flow ratio	1000°C
Lam D. K. W., 1984	$SiH_4 + N_2O + NH_3$	$SiH_4/N_2O/NH_3$ flow ratio	Not specified
Bruno F., 1991	$SiH_4 + N_2O + NH_3$	$SiH_4/N_2O/NH_3$ flow ratio	1100°C
Yokohama S., 1995	$SiH_4 + N_2O + NH_3$	$SiH_4/N_2O/NH_3$ flow ratio	Not specified
Agnihotri O. P., 1997	**$SiH_4 + N_2O + NH_3$**	**$SiH_4/N_2O/NH_3$ flow ratio**	**700-900°C**
Germann R., 1999	$SiH_4 + N_2O + NH_3$	Unknown	1100°C
Offrein B., 1999	$SiH_4 + N_2O + NH_3$	Unknown	1150°C
Hoffmann M., 1995	$SiH_4 + N_2O + NH_3 + Ar$	$SiH_4/N_2O/NH_3/Ar$ flow ratio	Not specified
Hoffmann M., 1997	$SiH_4 + N_2O + NH_3 + Ar$	$SiH_4/N_2O/NH_3/Ar$ flow ratio	Not specified
Tu Y., 1995	$SiH_4 + N_2O + NH_3 + N_2$	$N_2O/(N_2O + NH_3)$ flow ratio	1050°C
Poenar D., 1997	$SiH_4 + N_2O + NH_3 + N_2$	$SiH_4/N_2O/NH_3/N_2$ flow ratio	850°C
Ridder R., 1998	$SiH_4 + N_2O + NH_3 + N_2$	$SiH_4/N_2O/NH_3/Ar$ flow ratio	1100°C
Worhoff K., 1999	$SiH_4 + N_2O + NH_3 + N_2$	$SiH_4/N_2O/NH_3/N_2$ flow ratio	1150°C
Bulat E.S., 1993	**$SiH_4 + N_2O + N_2 + O_2 + He + CF_4$**	**$SiH_4/(N_2O/N_2)/O_2/CF_4$ flow ratio**	**425°C**
This Patent Application	**$SiH_4 + N_2O + PH_3 + N_2$**	**Patented Pending Method**	**650°C**

Figure 2

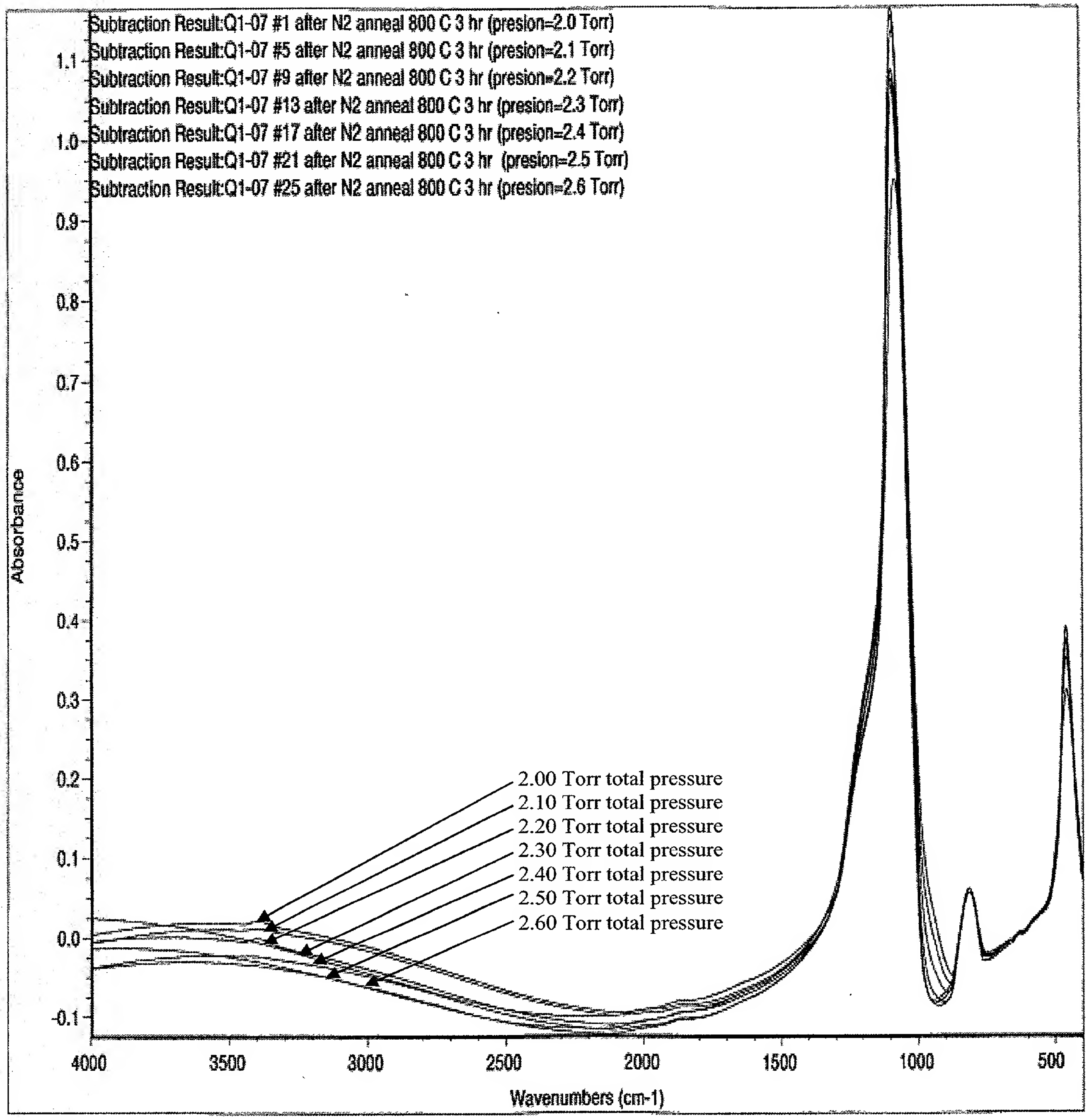
		HO-H	SiO-H	SiN-H	Si:N-H	Si-H	Si=O	N=N	Si-O-Si	Si-O-Si	Si-ON	Si-OH	Si-O-Si	Si-O-Si
FTIR 1st mode (cm-1)	Min	**3550**	**3470**	**3380**	**3300**	**2210**	**1800**	**1530**	**1080**	**1000**	**910**	**860**	**740**	**410**
	Ave	**3650**	**3510**	**3420**	**3380**	**2260**	**1875**	**1555**	**1180**	**1080**	**950**	**885**	**810**	**460**
	Max	**3750**	**3550**	**3460**	**3460**	**2310**	**1950**	**1580**	**1280**	**1160**	**990**	**910**	**880**	**510**
1st mode (µm)	Min	2.817	2.882	2.959	3.030	4.525	5.556	6.536	9.259	10.000	10.989	11.628	13.514	24.390
	Ave	2.740	2.849	2.924	2.959	4.425	5.333	6.431	8.475	9.259	10.526	11.299	12.346	21.739
	Max	2.667	2.817	2.890	2.890	4.329	5.128	6.329	7.813	8.621	10.101	10.989	11.364	19.608
2nd mode (µm)	Min	**1.408**	**1.441**	**1.479**	**1.515**	2.262	2.778	3.268	4.630	5.000	5.495	5.814	6.757	12.195
	Ave	**1.370**	**1.425**	**1.462**	**1.479**	2.212	2.667	3.215	4.237	4.630	5.263	5.650	6.173	10.870
	Max	**1.333**	**1.408**	**1.445**	**1.445**	2.165	2.564	3.165	3.906	4.310	5.051	5.495	5.682	9.804
3rd mode (µm)	Min	0.939	0.961	0.986	1.010	**1.508**	1.852	2.179	3.086	3.333	3.663	3.876	4.505	8.130
	Ave	0.913	0.950	0.975	0.986	**1.475**	1.778	2.144	2.825	3.086	3.509	3.766	4.115	7.246
	Max	0.889	0.939	0.963	0.963	**1.443**	1.709	2.110	2.604	2.874	3.367	3.663	3.788	6.536
4th mode (µm)	Min	0.704	0.720	0.740	0.758	1.131	**1.389**	1.634	2.315	2.500	2.747	2.907	3.378	6.098
	Ave	0.685	0.712	0.731	0.740	1.106	**1.333**	1.608	2.119	2.315	2.632	2.825	3.086	5.435
	Max	0.667	0.704	0.723	0.723	1.082	1.282	1.582	1.953	2.155	2.525	2.747	2.841	4.902
5th mode (µm)	Min	0.563	0.576	0.592	0.606	0.905	1.111	**1.307**	1.852	2.000	2.198	2.326	2.703	4.878
	Ave	0.548	0.570	0.585	0.592	0.885	1.067	1.286	1.695	1.852	2.105	2.260	2.469	4.348
	Max	0.533	0.563	0.578	0.578	0.866	1.026	1.266	1.563	1.724	2.020	2.198	2.273	3.922
6th mode (µm)	Min	0.469	0.480	0.493	0.505	0.754	0.926	1.089	**1.543**	1.667	1.832	1.938	2.252	4.065
	Ave	0.457	0.475	0.487	0.493	0.737	0.889	1.072	**1.412**	**1.543**	1.754	1.883	2.058	3.623
	Max	0.444	0.469	0.482	0.482	0.722	0.855	1.055	**1.302**	**1.437**	1.684	1.832	1.894	3.268
7th mode (µm)	Min	0.402	0.412	0.423	0.433	0.646	0.794	0.934	**1.323**	**1.429**	1.570	1.661	1.931	3.484
	Ave	0.391	0.407	0.418	0.423	0.632	0.762	0.919	1.211	**1.323**	**1.504**	1.614	1.764	3.106
	Max	0.381	0.402	0.413	0.413	0.618	0.733	0.904	1.116	1.232	**1.443**	1.570	1.623	2.801
8th mode (µm)	Min	0.352	0.360	0.370	0.379	0.566	0.694	0.817	1.157	1.250	**1.374**	**1.453**	1.689	3.049
	Ave	0.342	0.356	0.365	0.370	0.553	0.667	0.804	1.059	1.157	**1.316**	**1.412**	**1.543**	2.717
	Max	0.333	0.352	0.361	0.361	0.541	0.641	0.791	0.977	1.078	1.263	**1.374**	**1.420**	2.451

Figure 3a



Subtraction Result:Q064 #14 AFTER FIRST ANNEAL N2 600 C 3 HRS - INITIAL
Subtraction Result:Q064 #16 AFTER FIRST ANNEAL N2 700 C 3 HRS - INITIAL
Subtraction Result:Q064 #18 APRES AFTER FIRST ANNEAL N2 800 C 3 HRS - INITIAL
Subtraction Result:Q064 #20 AFTER FIRST ANNEAL N2 900 C 3 HRS - INITIAL
Subtraction Result:QO-64 #22 AFTER FIRST ANNEAL N2 1000C 3HRS - INITIAL
Subtraction Result:QO-64 #24 AFTER FIRST ANNEAL N2 1100C 3HRS - INITIAL
Subtraction Result:q0641u #24 after deposition - initial
180 minutes thermal treatment at 1100°C in Nitrogen
180 minutes thermal treatment at 1000°C in Nitrogen
180 minutes thermal treatment at 900°C in Nitrogen
180 minutes thermal treatment at 800°C in Nitrogen
180 minutes thermal treatment at 700°C in Nitrogen
180 minutes thermal treatment at 600°C in Nitrogen
No thermal treatment
Absorbance
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)

Figure 3b



Subtraction Result:Q1-07 #1 after N2 anneal 800 C 3 hr (presion=2.0 Torr)
Subtraction Result:Q1-07 #5 after N2 anneal 800 C 3 hr (presion=2.1 Torr)
Subtraction Result:Q1-07 #9 after N2 anneal 800 C 3 hr (presion=2.2 Torr)
Subtraction Result:Q1-07 #13 after N2 anneal 800 C 3 hr (presion=2.3 Torr)
Subtraction Result:Q1-07 #17 after N2 anneal 800 C 3 hr (presion=2.4 Torr)
Subtraction Result:Q1-07 #21 after N2 anneal 800 C 3 hr (presion=2.5 Torr)
Subtraction Result:Q1-07 #25 after N2 anneal 800 C 3 hr (presion=2.6 Torr)
Absorbance
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
2.00 Torr total pressure
2.10 Torr total pressure
2.20 Torr total pressure
2.30 Torr total pressure
2.40 Torr total pressure
2.50 Torr total pressure
2.60 Torr total pressure
4000
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)

Figure 3c

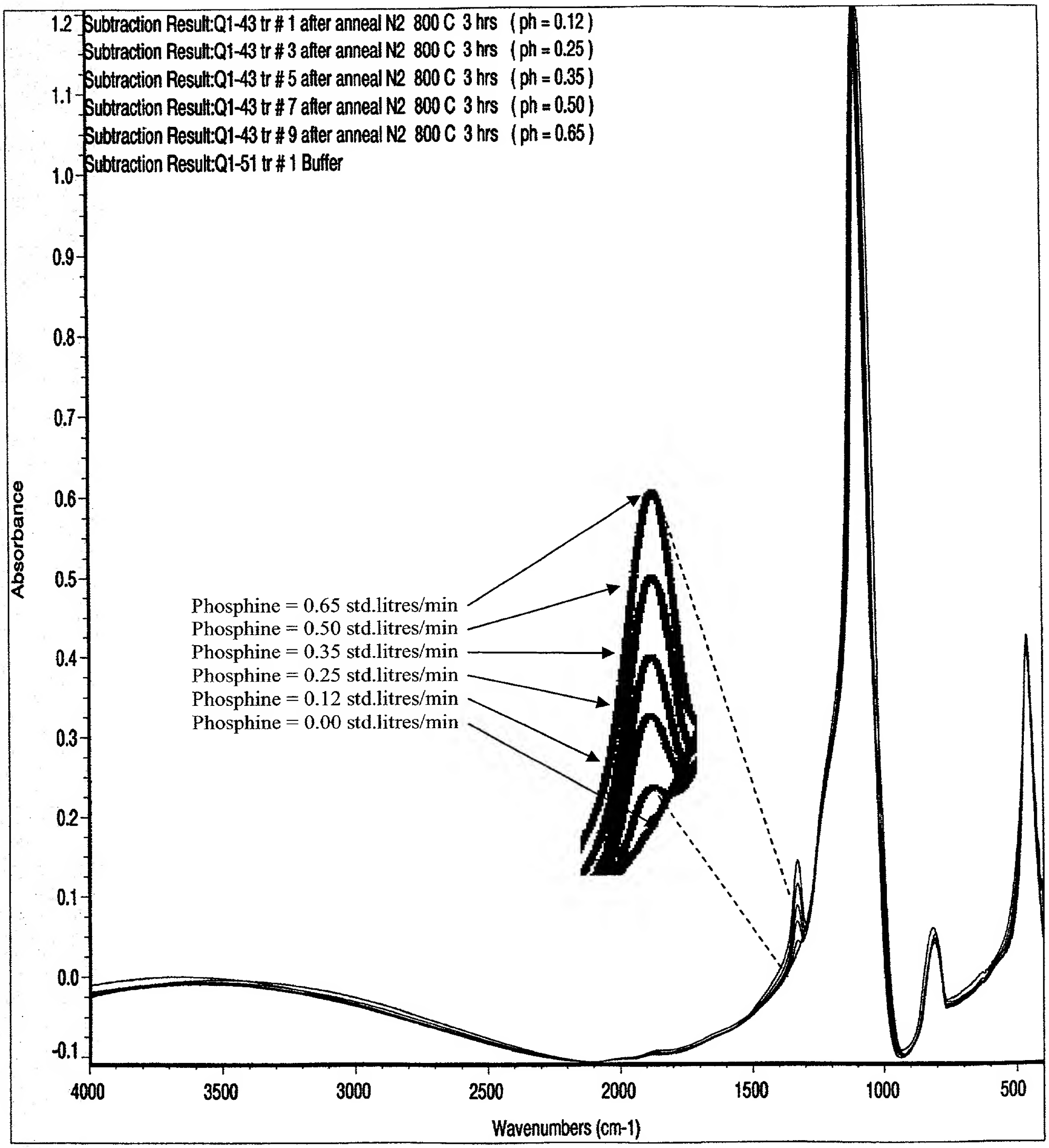

Subtraction Result:Q1-43 tr # 1 after anneal N2 800 C 3 hrs (ph = 0.12)
Subtraction Result:Q1-43 tr # 3 after anneal N2 800 C 3 hrs (ph = 0.25)
Subtraction Result:Q1-43 tr # 5 after anneal N2 800 C 3 hrs (ph = 0.35)
Subtraction Result:Q1-43 tr # 7 after anneal N2 800 C 3 hrs (ph = 0.50)
Subtraction Result:Q1-43 tr # 9 after anneal N2 800 C 3 hrs (ph = 0.65)
Subtraction Result:Q1-51 tr # 1 Buffer
Phosphine = 0.65 std.litres/min
Phosphine = 0.50 std.litres/min
Phosphine = 0.35 std.litres/min
Phosphine = 0.25 std.litres/min
Phosphine = 0.12 std.litres/min
Phosphine = 0.00 std.litres/min
Absorbance
Wavenumbers (cm-1)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
4000
3500
3000
2500
2000
1500
1000
500

Figure 3d

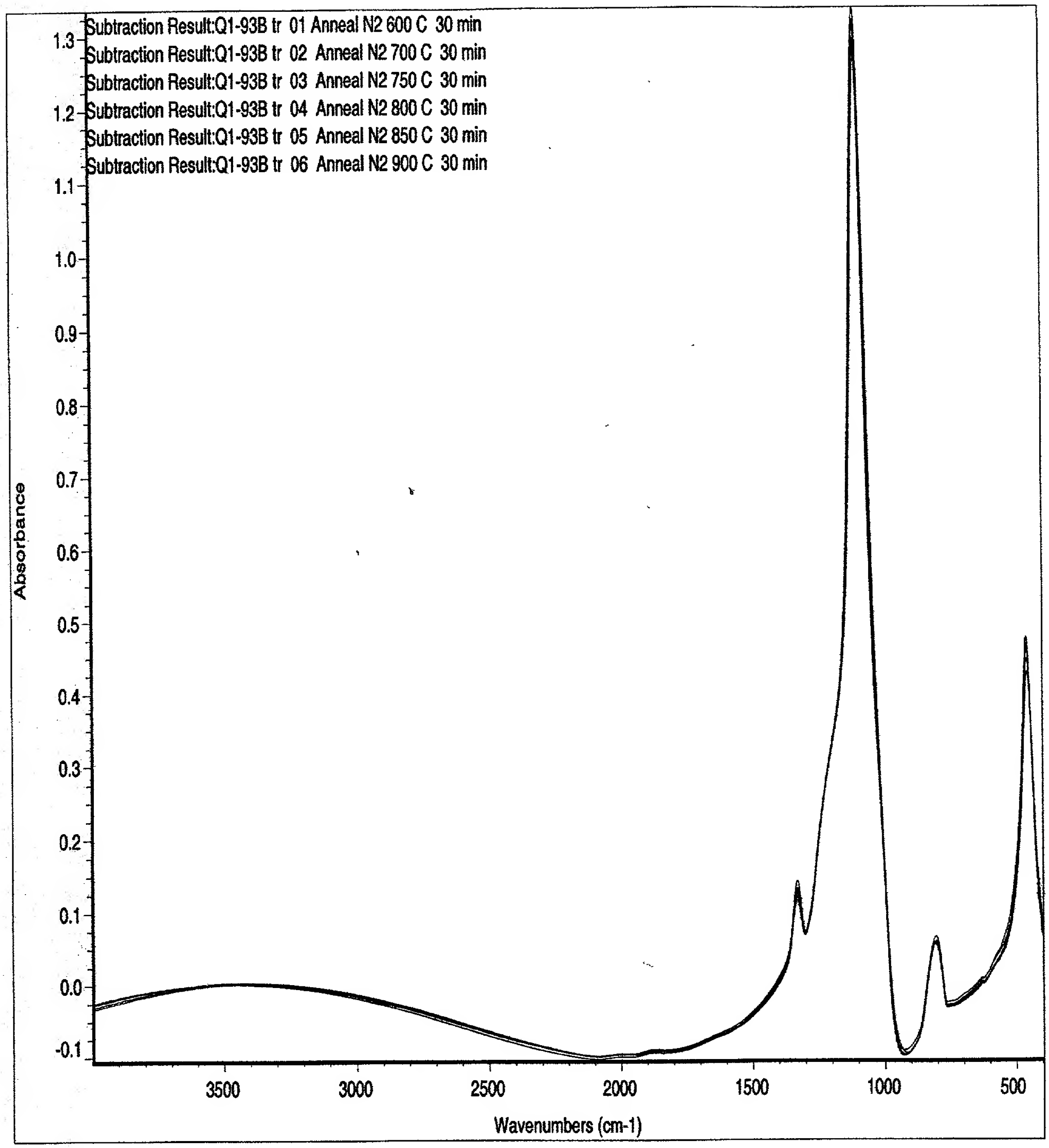

Subtraction Result:Q1-93B tr 01 Anneal N2 600 C 30 min
Subtraction Result:Q1-93B tr 02 Anneal N2 700 C 30 min
Subtraction Result:Q1-93B tr 03 Anneal N2 750 C 30 min
Subtraction Result:Q1-93B tr 04 Anneal N2 800 C 30 min
Subtraction Result:Q1-93B tr 05 Anneal N2 850 C 30 min
Subtraction Result:Q1-93B tr 06 Anneal N2 900 C 30 min
Absorbance
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)

Figure 4a

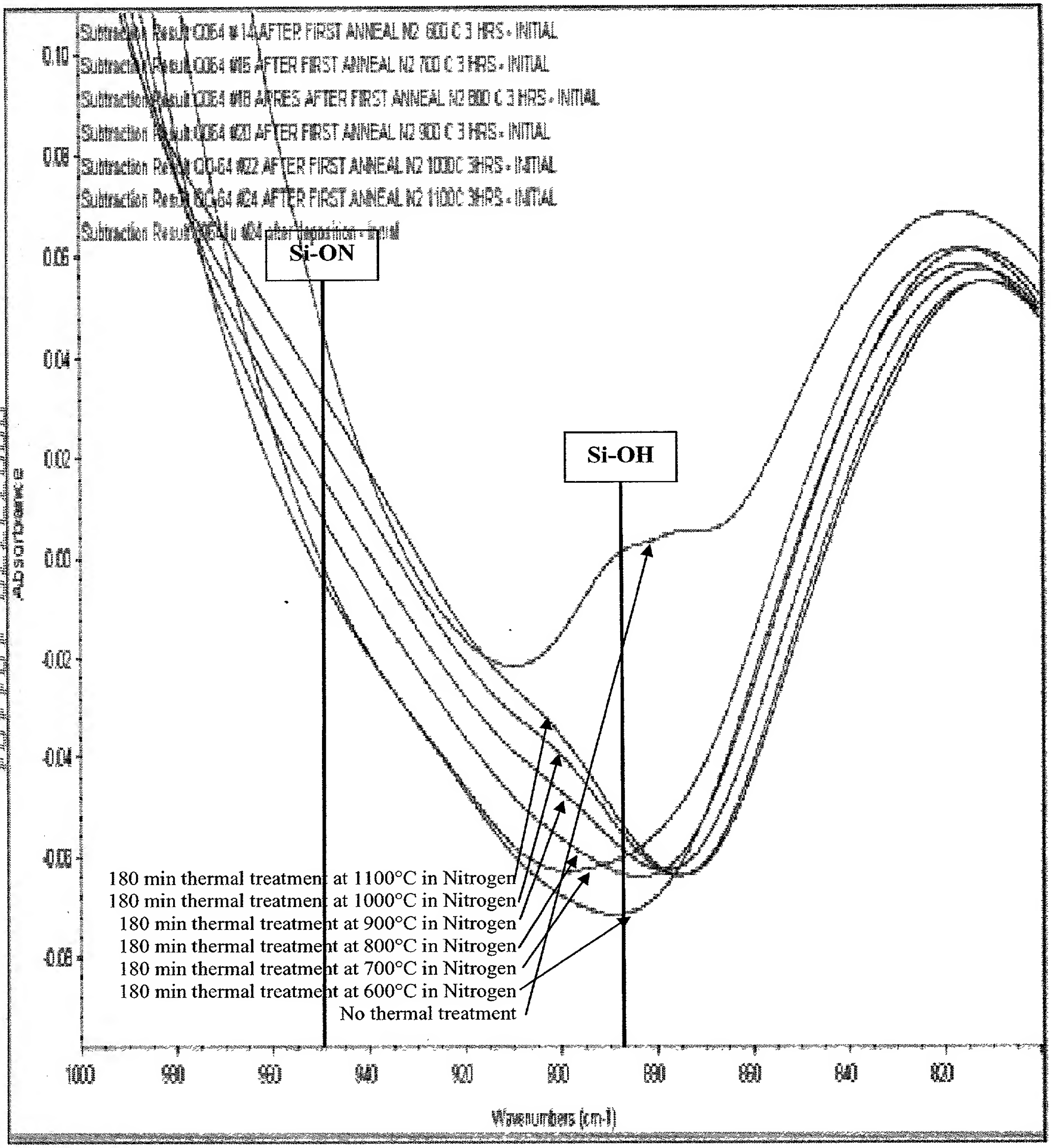
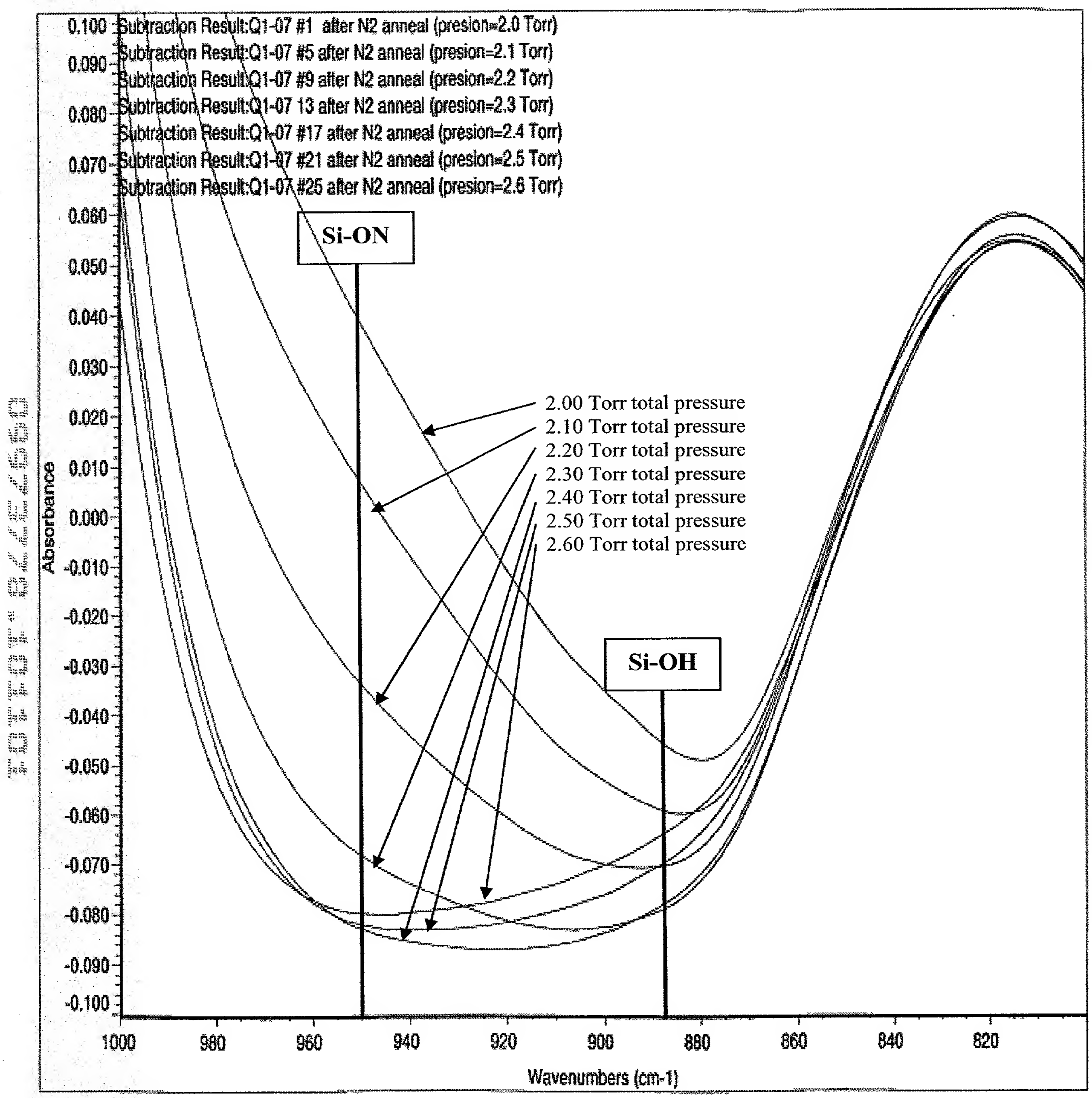

Subtraction Result:QD64 # 14 AFTER FIRST ANNEAL N2 600 C 3 HRS - INITIAL
Subtraction Result:QD64 #16 AFTER FIRST ANNEAL N2 700 C 3 HRS - INITIAL
Subtraction Result:QD64 #18 ARRES AFTER FIRST ANNEAL N2 800 C 3 HRS - INITIAL
Subtraction Result:QD64 #20 AFTER FIRST ANNEAL N2 900 C 3 HRS - INITIAL
Subtraction Result:QD-64 #22 AFTER FIRST ANNEAL N2 1000C 3HRS - INITIAL
Subtraction Result:QD-64 #24 AFTER FIRST ANNEAL N2 1100C 3HRS - INITIAL
Subtraction Result:QD64 u #24 after deposition - initial
Si-ON
Si-OH
180 min thermal treatment at 1100°C in Nitrogen
180 min thermal treatment at 1000°C in Nitrogen
180 min thermal treatment at 900°C in Nitrogen
180 min thermal treatment at 800°C in Nitrogen
180 min thermal treatment at 700°C in Nitrogen
180 min thermal treatment at 600°C in Nitrogen
No thermal treatment
Absorbance
Wavenumbers (cm-1)
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
1000
980
960
940
920
900
880
860
840
820

Figure 4b



Subtraction Result:Q1-07 #1 after N2 anneal (presion=2.0 Torr)
Subtraction Result:Q1-07 #5 after N2 anneal (presion=2.1 Torr)
Subtraction Result:Q1-07 #9 after N2 anneal (presion=2.2 Torr)
Subtraction Result:Q1-07 13 after N2 anneal (presion=2.3 Torr)
Subtraction Result:Q1-07 #17 after N2 anneal (presion=2.4 Torr)
Subtraction Result:Q1-07 #21 after N2 anneal (presion=2.5 Torr)
Subtraction Result:Q1-07 #25 after N2 anneal (presion=2.6 Torr)
Si-ON
Si-OH
2.00 Torr total pressure
2.10 Torr total pressure
2.20 Torr total pressure
2.30 Torr total pressure
2.40 Torr total pressure
2.50 Torr total pressure
2.60 Torr total pressure
Absorbance
Wavenumbers (cm-1)
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
-0.010
-0.020
-0.030
-0.040
-0.050
-0.060
-0.070
-0.080
-0.090
-0.100
1000
980
960
940
920
900
880
860
840
820

Figure 4c

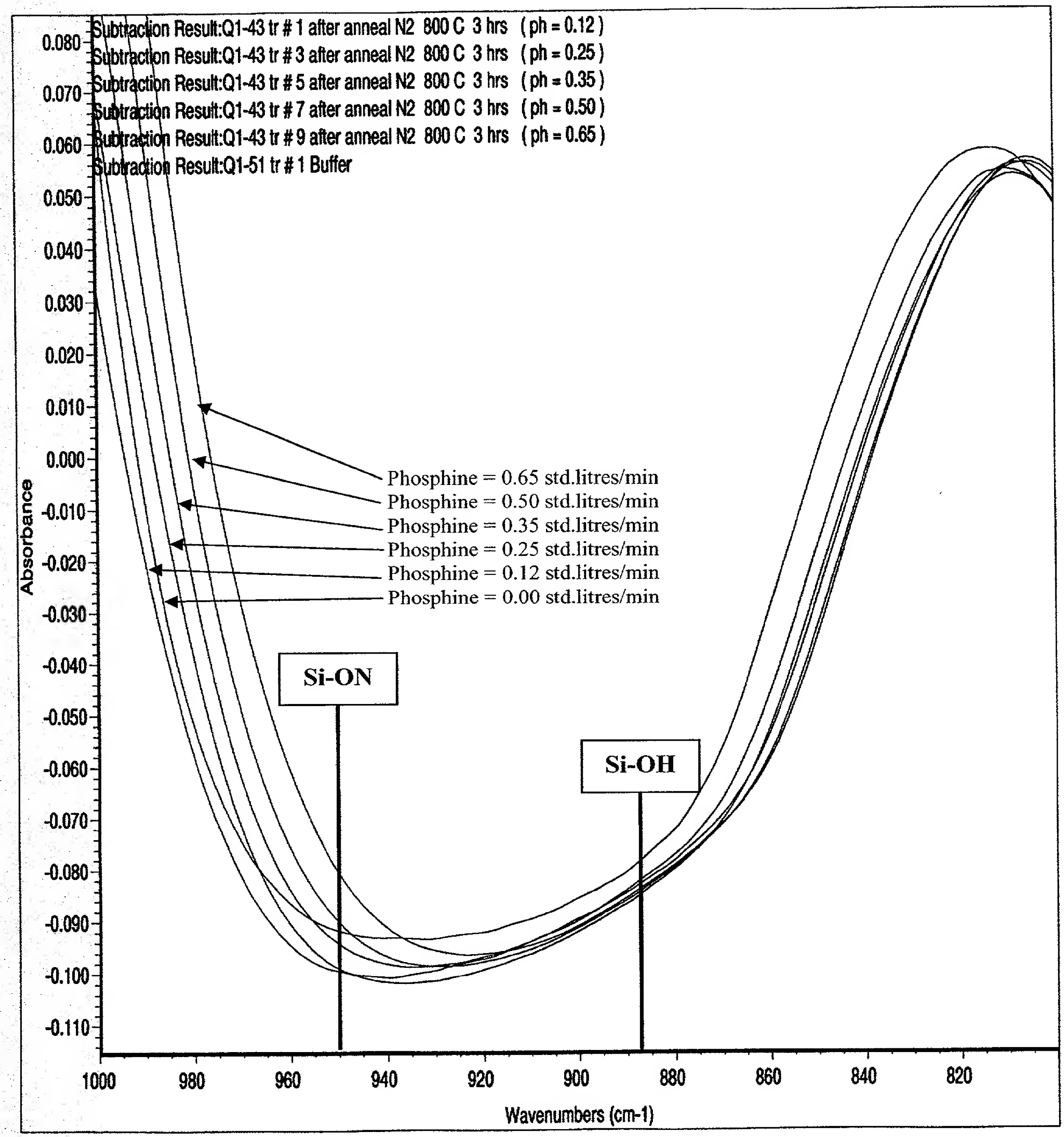
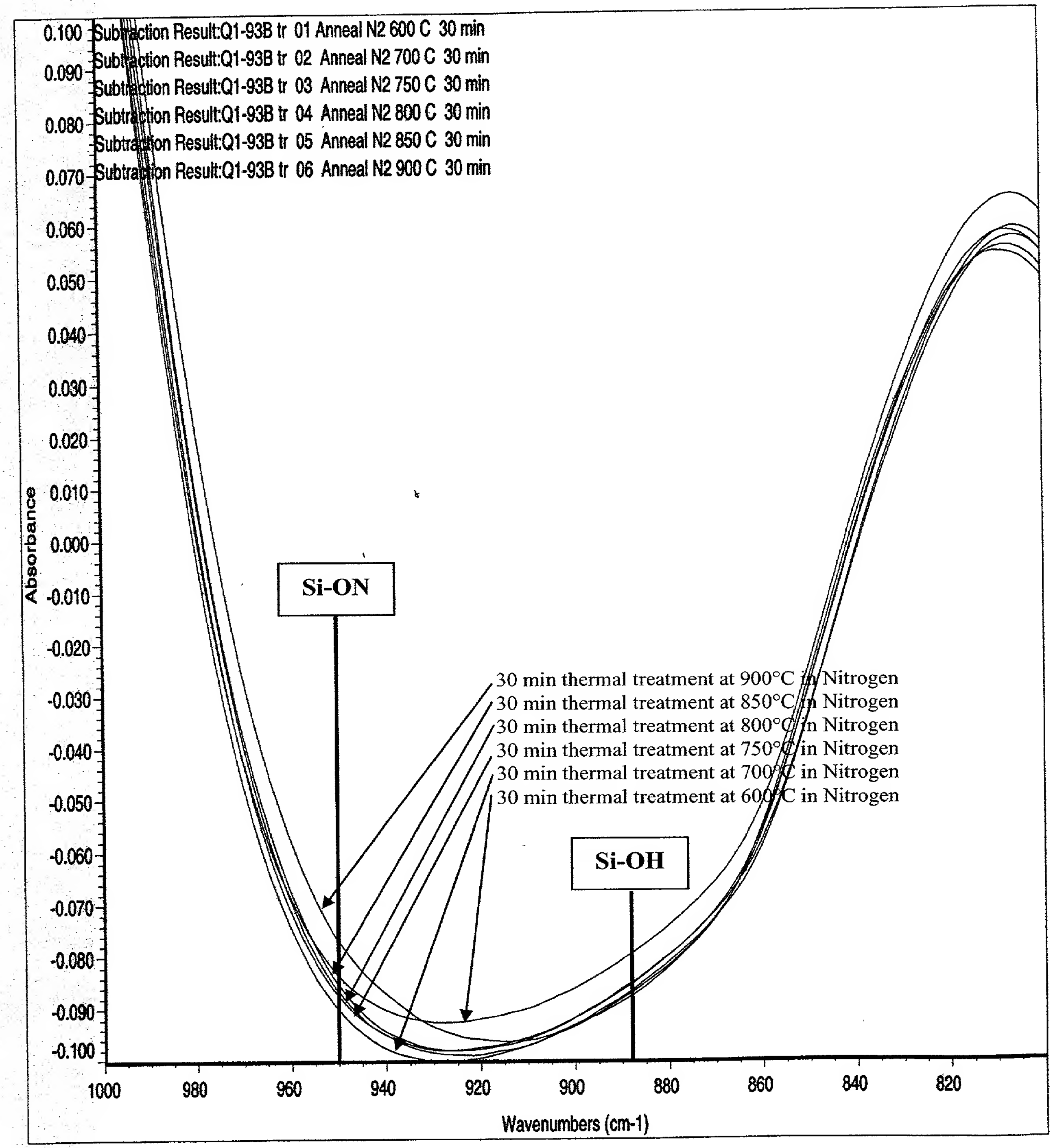
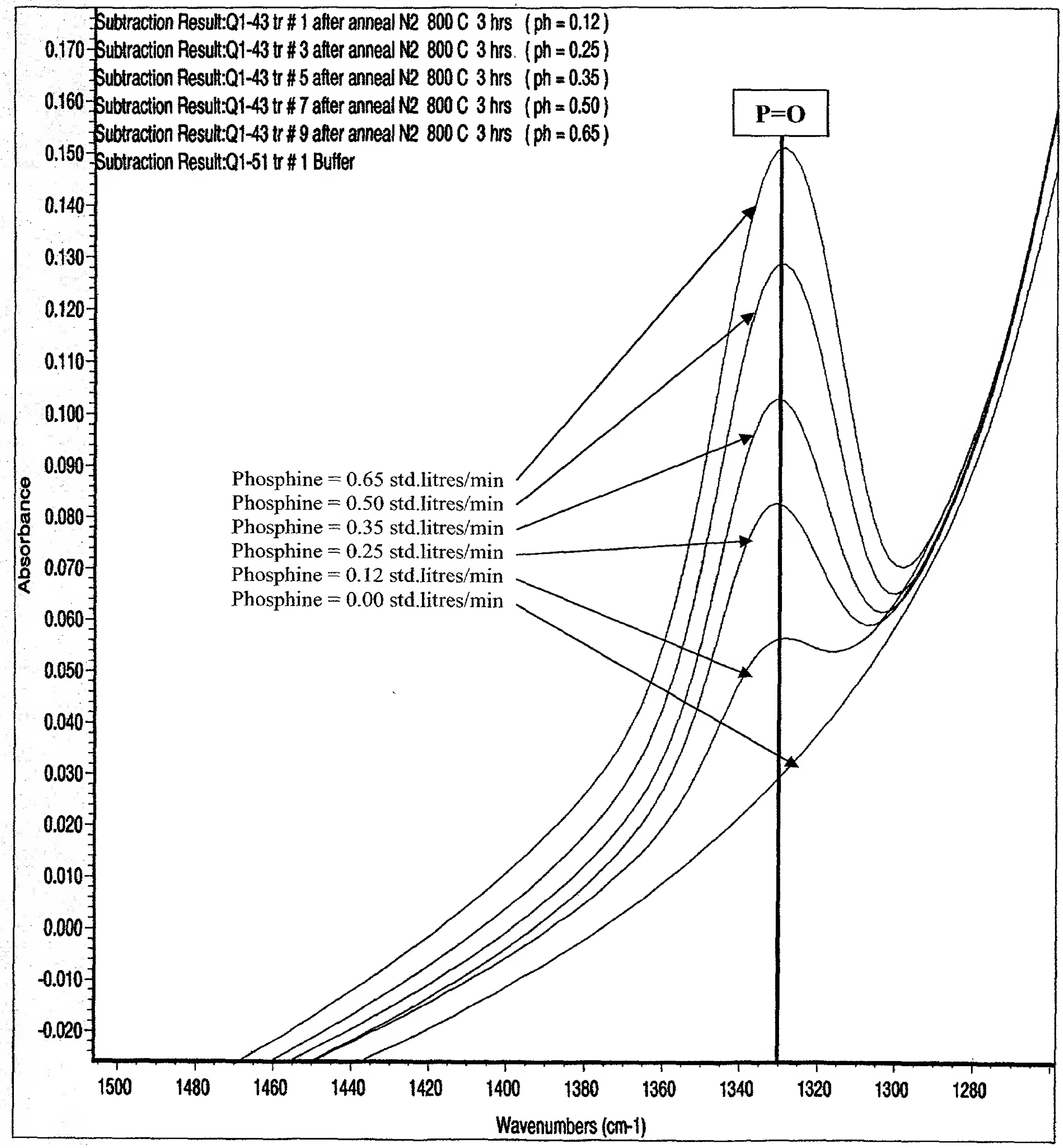

Subtraction Result:Q1-43 tr # 1 after anneal N2 800 C 3 hrs (ph = 0.12)
Subtraction Result:Q1-43 tr # 3 after anneal N2 800 C 3 hrs (ph = 0.25)
Subtraction Result:Q1-43 tr # 5 after anneal N2 800 C 3 hrs (ph = 0.35)
Subtraction Result:Q1-43 tr # 7 after anneal N2 800 C 3 hrs (ph = 0.50)
Subtraction Result:Q1-43 tr # 9 after anneal N2 800 C 3 hrs (ph = 0.65)
Subtraction Result:Q1-51 tr # 1 Buffer
Phosphine = 0.65 std.litres/min
Phosphine = 0.50 std.litres/min
Phosphine = 0.35 std.litres/min
Phosphine = 0.25 std.litres/min
Phosphine = 0.12 std.litres/min
Phosphine = 0.00 std.litres/min
Si-ON
Si-OH
Absorbance
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
-0.010
-0.020
-0.030
-0.040
-0.050
-0.060
-0.070
-0.080
-0.090
-0.100
-0.110
1000
980
960
940
920
900
880
860
840
820
Wavenumbers (cm-1)

Figure 4d



Subtraction Result:Q1-93B tr 01 Anneal N2 600 C 30 min
Subtraction Result:Q1-93B tr 02 Anneal N2 700 C 30 min
Subtraction Result:Q1-93B tr 03 Anneal N2 750 C 30 min
Subtraction Result:Q1-93B tr 04 Anneal N2 800 C 30 min
Subtraction Result:Q1-93B tr 05 Anneal N2 850 C 30 min
Subtraction Result:Q1-93B tr 06 Anneal N2 900 C 30 min
Absorbance
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
-0.010
-0.020
-0.030
-0.040
-0.050
-0.060
-0.070
-0.080
-0.090
-0.100
Si-ON
Si-OH
30 min thermal treatment at 900°C in Nitrogen
30 min thermal treatment at 850°C in Nitrogen
30 min thermal treatment at 800°C in Nitrogen
30 min thermal treatment at 750°C in Nitrogen
30 min thermal treatment at 700°C in Nitrogen
30 min thermal treatment at 600°C in Nitrogen
1000
980
960
940
920
900
880
860
840
820
Wavenumbers (cm-1)

Figure 5c



Subtraction Result:Q1-43 tr # 1 after anneal N2 800 C 3 hrs (ph = 0.12)
Subtraction Result:Q1-43 tr # 3 after anneal N2 800 C 3 hrs (ph = 0.25)
Subtraction Result:Q1-43 tr # 5 after anneal N2 800 C 3 hrs (ph = 0.35)
Subtraction Result:Q1-43 tr # 7 after anneal N2 800 C 3 hrs (ph = 0.50)
Subtraction Result:Q1-43 tr # 9 after anneal N2 800 C 3 hrs (ph = 0.65)
Subtraction Result:Q1-51 tr # 1 Buffer
P=O
Phosphine = 0.65 std.litres/min
Phosphine = 0.50 std.litres/min
Phosphine = 0.35 std.litres/min
Phosphine = 0.25 std.litres/min
Phosphine = 0.12 std.litres/min
Phosphine = 0.00 std.litres/min
Absorbance
Wavenumbers (cm-1)

Figure 5d

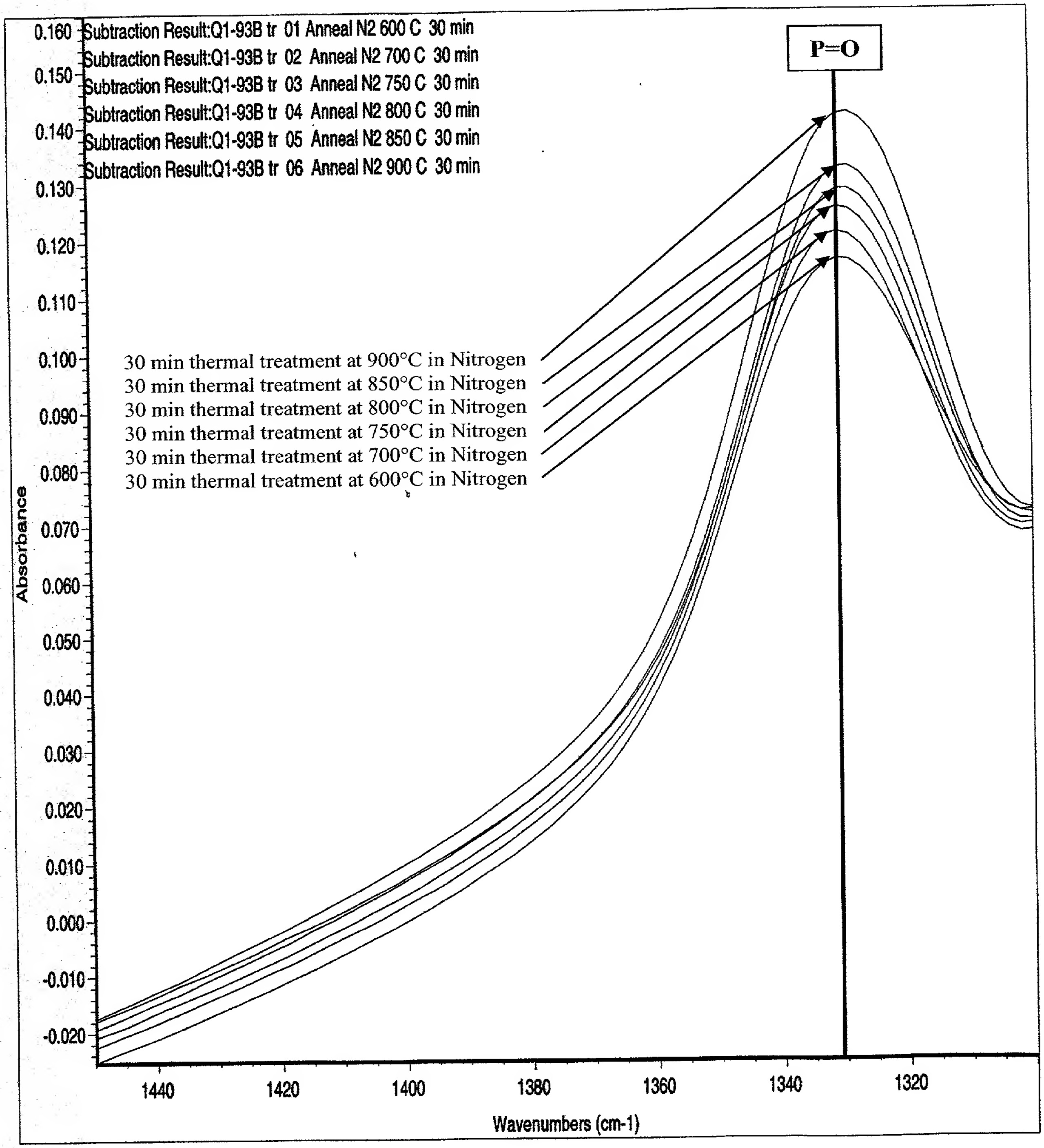
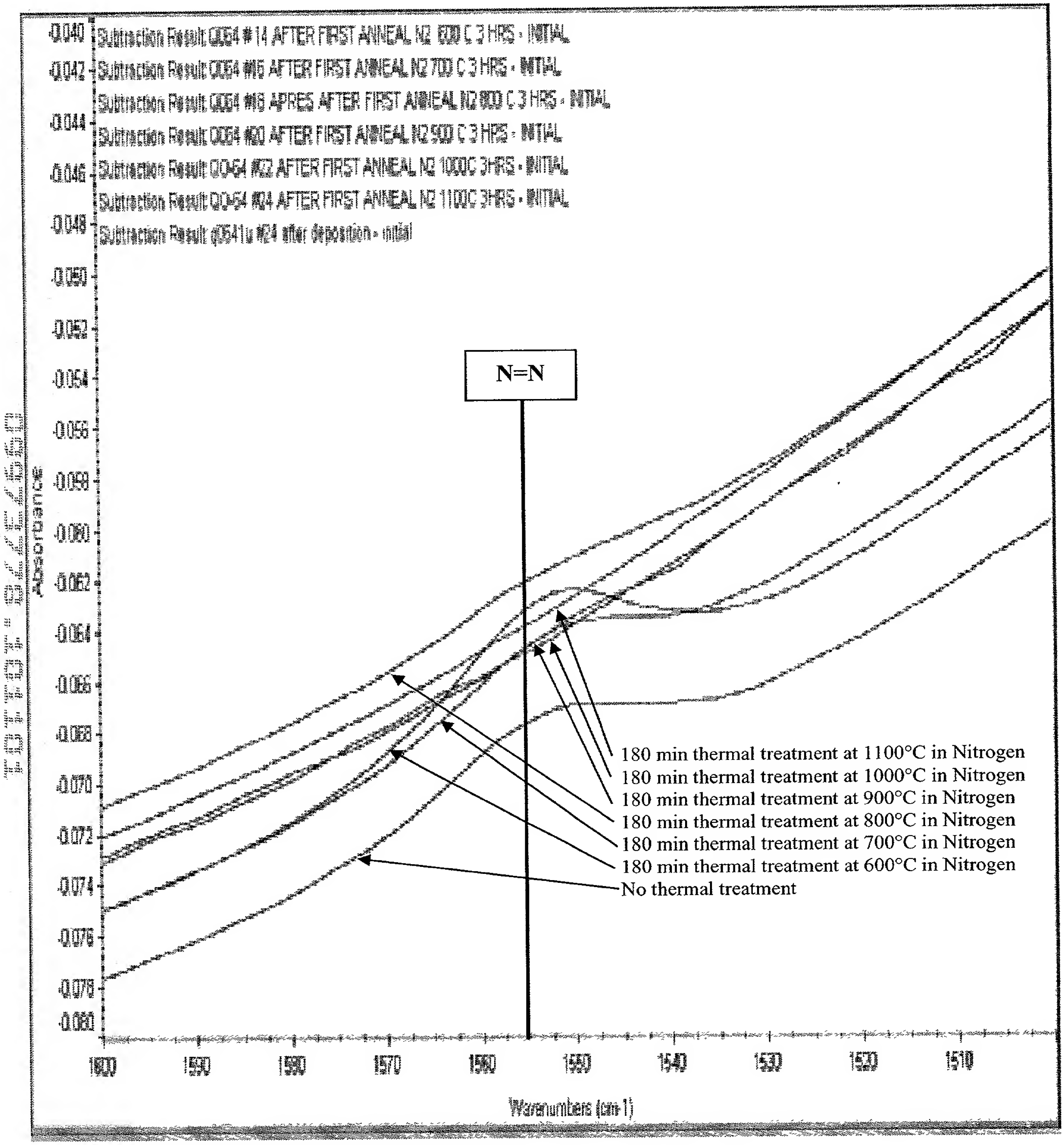
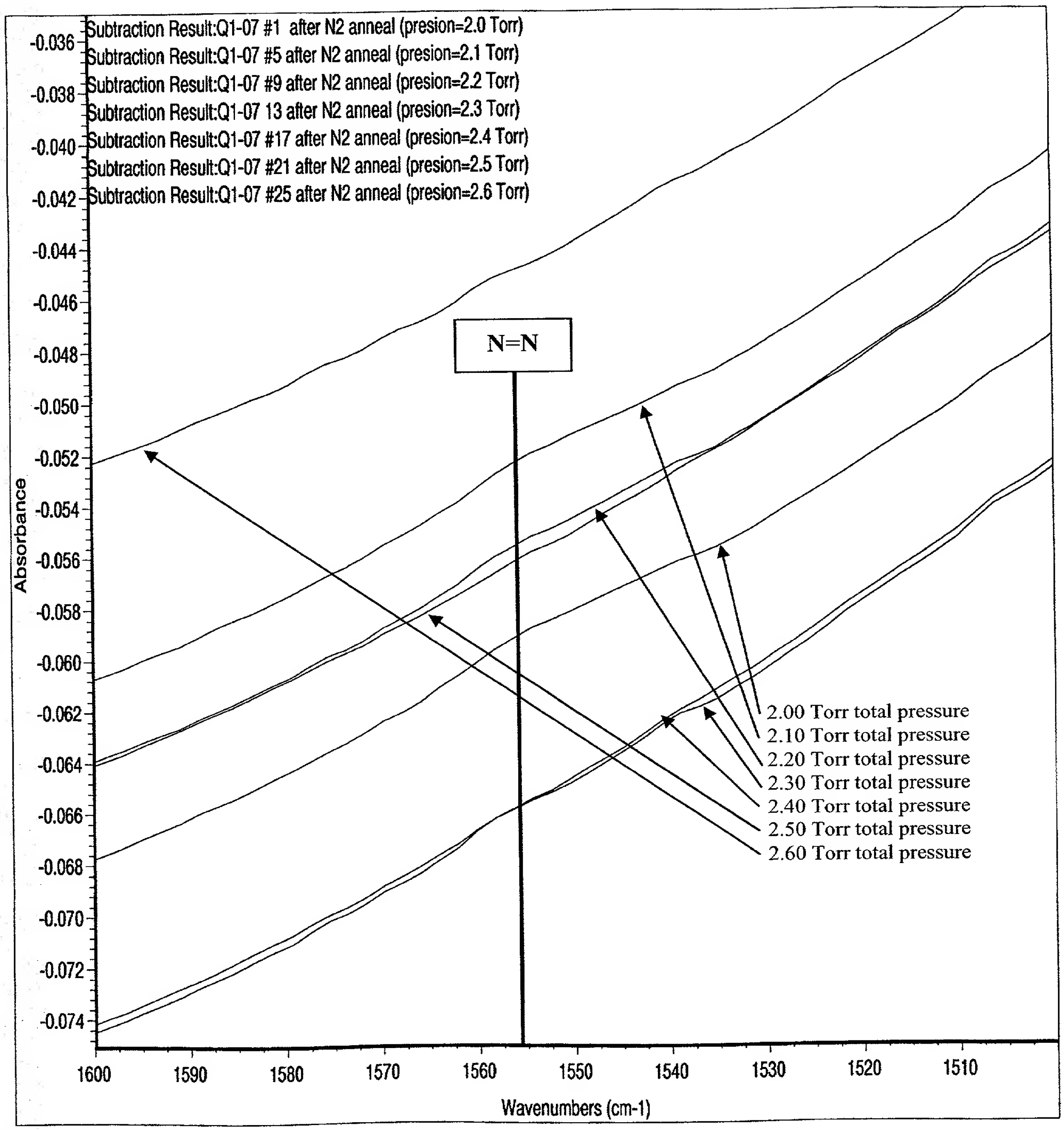

Subtraction Result:Q1-93B tr 01 Anneal N2 600 C 30 min
Subtraction Result:Q1-93B tr 02 Anneal N2 700 C 30 min
Subtraction Result:Q1-93B tr 03 Anneal N2 750 C 30 min
Subtraction Result:Q1-93B tr 04 Anneal N2 800 C 30 min
Subtraction Result:Q1-93B tr 05 Anneal N2 850 C 30 min
Subtraction Result:Q1-93B tr 06 Anneal N2 900 C 30 min
P=O
30 min thermal treatment at 900°C in Nitrogen
30 min thermal treatment at 850°C in Nitrogen
30 min thermal treatment at 800°C in Nitrogen
30 min thermal treatment at 750°C in Nitrogen
30 min thermal treatment at 700°C in Nitrogen
30 min thermal treatment at 600°C in Nitrogen
Absorbance
0.160
0.150
0.140
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
-0.010
-0.020
1440
1420
1400
1380
1360
1340
1320
Wavenumbers (cm-1)

Figure 6a



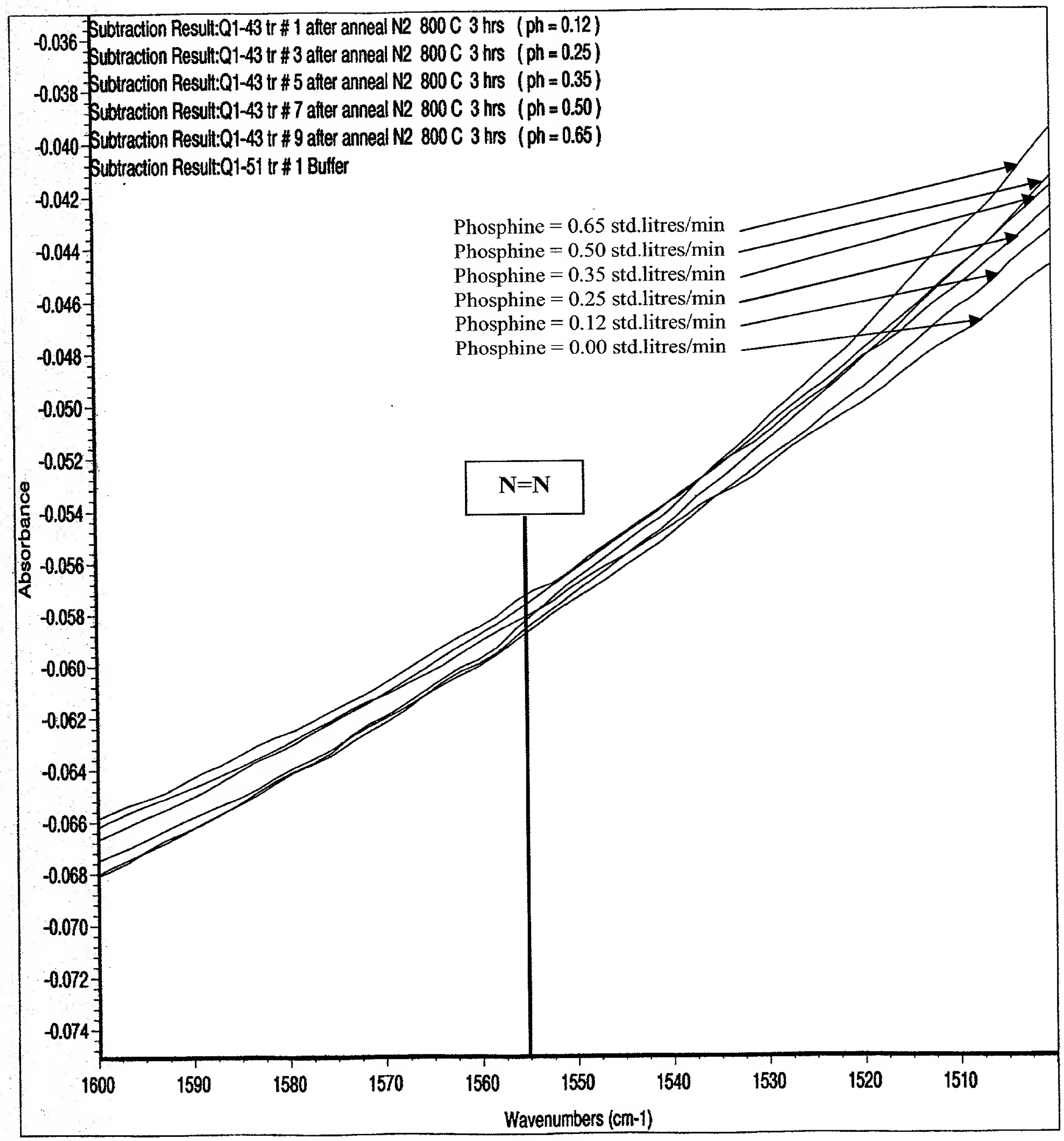
Subtraction Result Q064 #14 AFTER FIRST ANNEAL N2 600 C 3 HRS - INITIAL
Subtraction Result Q064 #16 AFTER FIRST ANNEAL N2 700 C 3 HRS - INITIAL
Subtraction Result Q064 #18 APRES AFTER FIRST ANNEAL N2 800 C 3 HRS - INITIAL
Subtraction Result Q064 #20 AFTER FIRST ANNEAL N2 900 C 3 HRS - INITIAL
Subtraction Result QO-64 #22 AFTER FIRST ANNEAL N2 1000C 3HRS - INITIAL
Subtraction Result QO-64 #24 AFTER FIRST ANNEAL N2 1100C 3HRS - INITIAL
Subtraction Result q0641u #24 after deposition - initial
N=N
Absorbance
Wavenumbers (cm-1)
-0.040
-0.042
-0.044
-0.046
-0.048
-0.050
-0.052
-0.054
-0.056
-0.058
-0.060
-0.062
-0.064
-0.066
-0.068
-0.070
-0.072
-0.074
-0.076
-0.078
-0.080
1600
1590
1580
1570
1560
1550
1540
1530
1520
1510
180 min thermal treatment at 1100°C in Nitrogen
180 min thermal treatment at 1000°C in Nitrogen
180 min thermal treatment at 900°C in Nitrogen
180 min thermal treatment at 800°C in Nitrogen
180 min thermal treatment at 700°C in Nitrogen
180 min thermal treatment at 600°C in Nitrogen
No thermal treatment

Figure 6b



Subtraction Result:Q1-07 #1 after N2 anneal (presion=2.0 Torr)
Subtraction Result:Q1-07 #5 after N2 anneal (presion=2.1 Torr)
Subtraction Result:Q1-07 #9 after N2 anneal (presion=2.2 Torr)
Subtraction Result:Q1-07 13 after N2 anneal (presion=2.3 Torr)
Subtraction Result:Q1-07 #17 after N2 anneal (presion=2.4 Torr)
Subtraction Result:Q1-07 #21 after N2 anneal (presion=2.5 Torr)
Subtraction Result:Q1-07 #25 after N2 anneal (presion=2.6 Torr)
N=N
2.00 Torr total pressure
2.10 Torr total pressure
2.20 Torr total pressure
2.30 Torr total pressure
2.40 Torr total pressure
2.50 Torr total pressure
2.60 Torr total pressure
Absorbance
-0.036
-0.038
-0.040
-0.042
-0.044
-0.046
-0.048
-0.050
-0.052
-0.054
-0.056
-0.058
-0.060
-0.062
-0.064
-0.066
-0.068
-0.070
-0.072
-0.074
1600
1590
1580
1570
1560
1550
1540
1530
1520
1510
Wavenumbers (cm-1)

Figure 6c



Subtraction Result:Q1-43 tr # 1 after anneal N2 800 C 3 hrs (ph = 0.12)
Subtraction Result:Q1-43 tr # 3 after anneal N2 800 C 3 hrs (ph = 0.25)
Subtraction Result:Q1-43 tr # 5 after anneal N2 800 C 3 hrs (ph = 0.35)
Subtraction Result:Q1-43 tr # 7 after anneal N2 800 C 3 hrs (ph = 0.50)
Subtraction Result:Q1-43 tr # 9 after anneal N2 800 C 3 hrs (ph = 0.65)
Subtraction Result:Q1-51 tr # 1 Buffer
Phosphine = 0.65 std.litres/min
Phosphine = 0.50 std.litres/min
Phosphine = 0.35 std.litres/min
Phosphine = 0.25 std.litres/min
Phosphine = 0.12 std.litres/min
Phosphine = 0.00 std.litres/min
N=N
Absorbance
-0.036
-0.038
-0.040
-0.042
-0.044
-0.046
-0.048
-0.050
-0.052
-0.054
-0.056
-0.058
-0.060
-0.062
-0.064
-0.066
-0.068
-0.070
-0.072
-0.074
1600
1590
1580
1570
1560
1550
1540
1530
1520
1510
Wavenumbers (cm-1)

Figure 6d

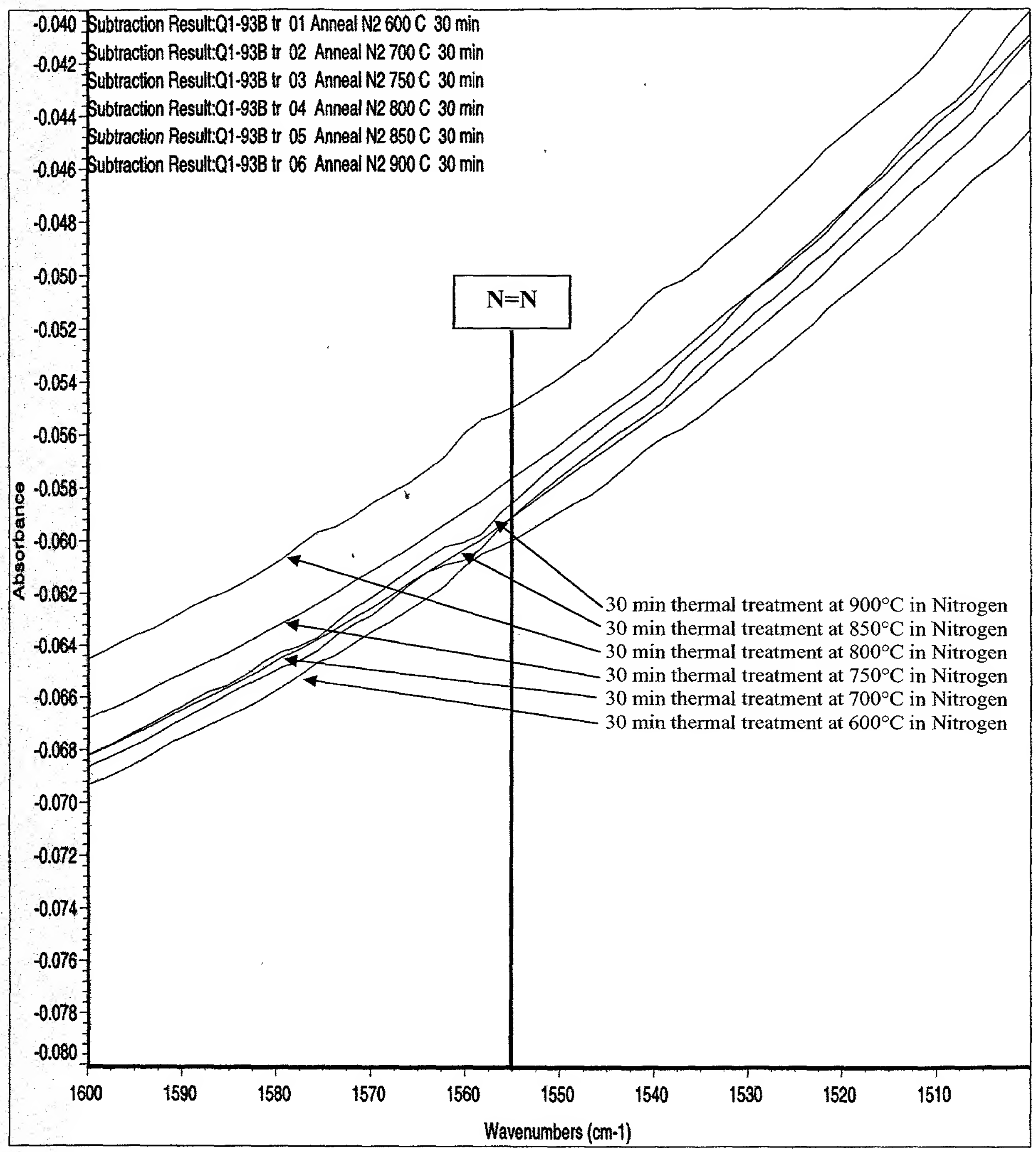
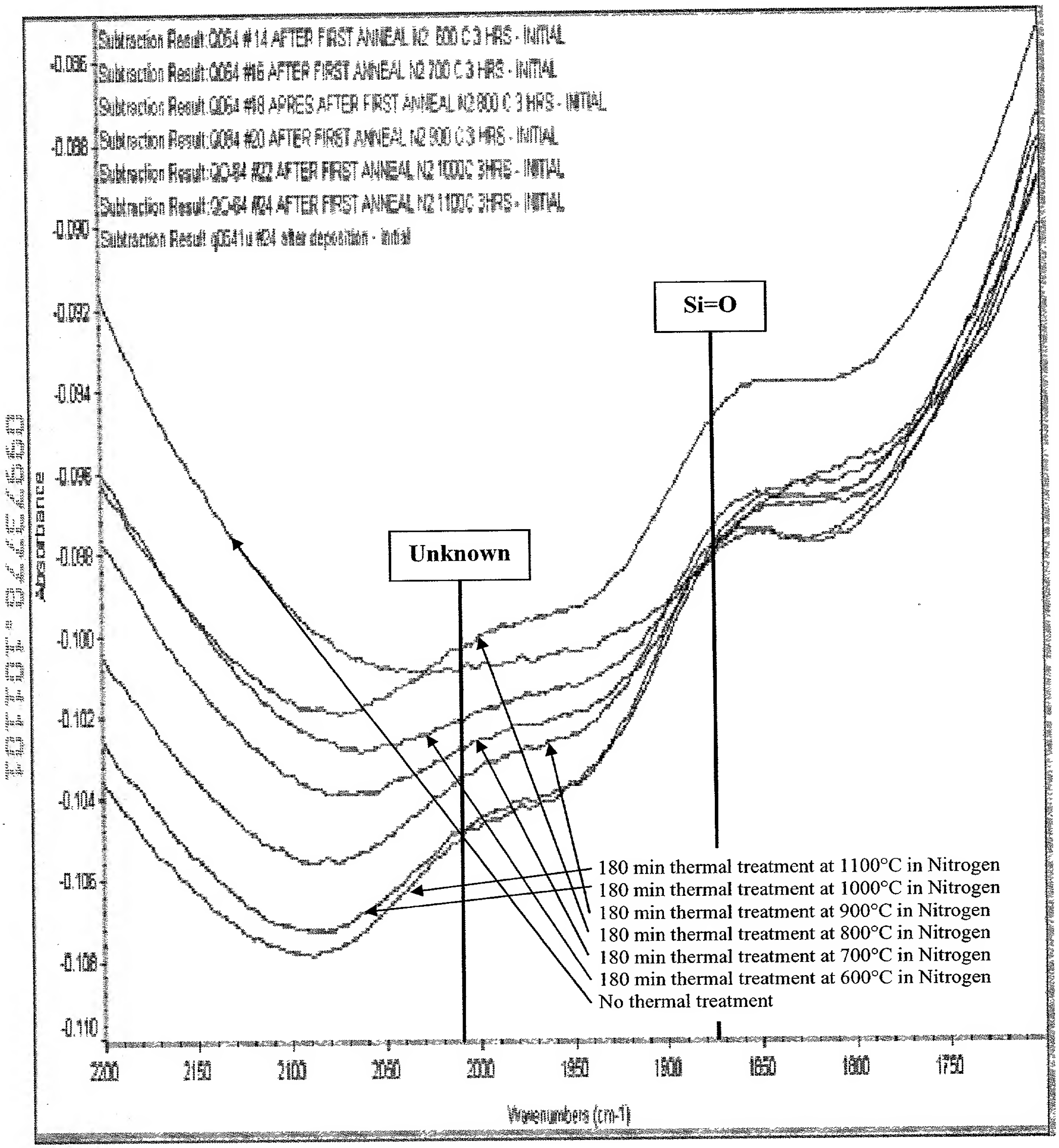
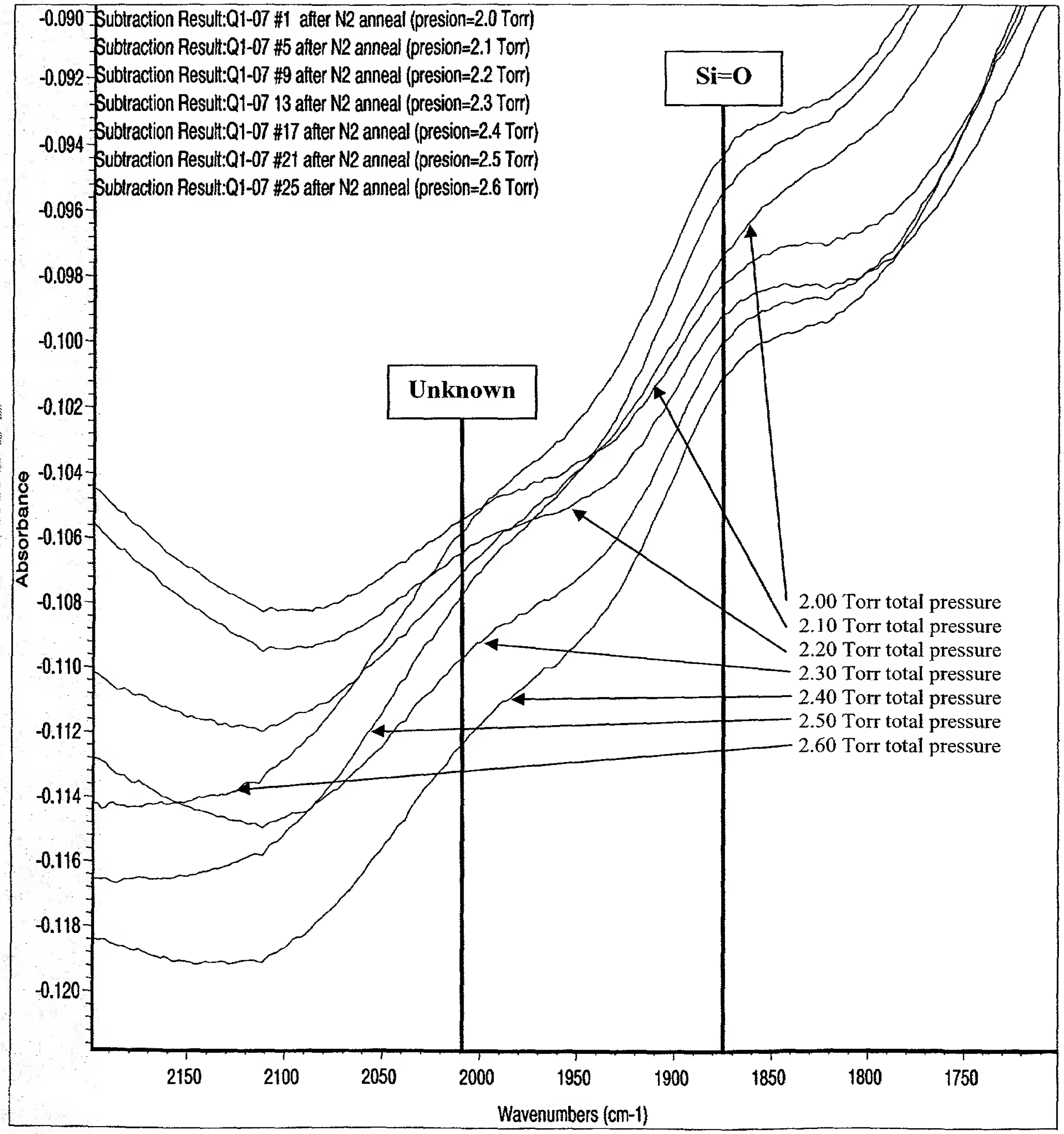

Subtraction Result:Q1-93B tr 01 Anneal N2 600 C 30 min
Subtraction Result:Q1-93B tr 02 Anneal N2 700 C 30 min
Subtraction Result:Q1-93B tr 03 Anneal N2 750 C 30 min
Subtraction Result:Q1-93B tr 04 Anneal N2 800 C 30 min
Subtraction Result:Q1-93B tr 05 Anneal N2 850 C 30 min
Subtraction Result:Q1-93B tr 06 Anneal N2 900 C 30 min
N=N
30 min thermal treatment at 900°C in Nitrogen
30 min thermal treatment at 850°C in Nitrogen
30 min thermal treatment at 800°C in Nitrogen
30 min thermal treatment at 750°C in Nitrogen
30 min thermal treatment at 700°C in Nitrogen
30 min thermal treatment at 600°C in Nitrogen
Absorbance
-0.040
-0.042
-0.044
-0.046
-0.048
-0.050
-0.052
-0.054
-0.056
-0.058
-0.060
-0.062
-0.064
-0.066
-0.068
-0.070
-0.072
-0.074
-0.076
-0.078
-0.080
1600
1590
1580
1570
1560
1550
1540
1530
1520
1510
Wavenumbers (cm-1)

Figure 7a



Si=O
Unknown
180 min thermal treatment at 1100°C in Nitrogen
180 min thermal treatment at 1000°C in Nitrogen
180 min thermal treatment at 900°C in Nitrogen
180 min thermal treatment at 800°C in Nitrogen
180 min thermal treatment at 700°C in Nitrogen
180 min thermal treatment at 600°C in Nitrogen
No thermal treatment
Absorbance
Wavenumbers (cm-1)

Figure 7b



Subtraction Result:Q1-07 #1 after N2 anneal (presion=2.0 Torr)
Subtraction Result:Q1-07 #5 after N2 anneal (presion=2.1 Torr)
Subtraction Result:Q1-07 #9 after N2 anneal (presion=2.2 Torr)
Subtraction Result:Q1-07 13 after N2 anneal (presion=2.3 Torr)
Subtraction Result:Q1-07 #17 after N2 anneal (presion=2.4 Torr)
Subtraction Result:Q1-07 #21 after N2 anneal (presion=2.5 Torr)
Subtraction Result:Q1-07 #25 after N2 anneal (presion=2.6 Torr)
Si=O
Unknown
2.00 Torr total pressure
2.10 Torr total pressure
2.20 Torr total pressure
2.30 Torr total pressure
2.40 Torr total pressure
2.50 Torr total pressure
2.60 Torr total pressure
Absorbance
-0.090
-0.092
-0.094
-0.096
-0.098
-0.100
-0.102
-0.104
-0.106
-0.108
-0.110
-0.112
-0.114
-0.116
-0.118
-0.120
2150
2100
2050
2000
1950
1900
1850
1800
1750
Wavenumbers (cm-1)

Figure 7c

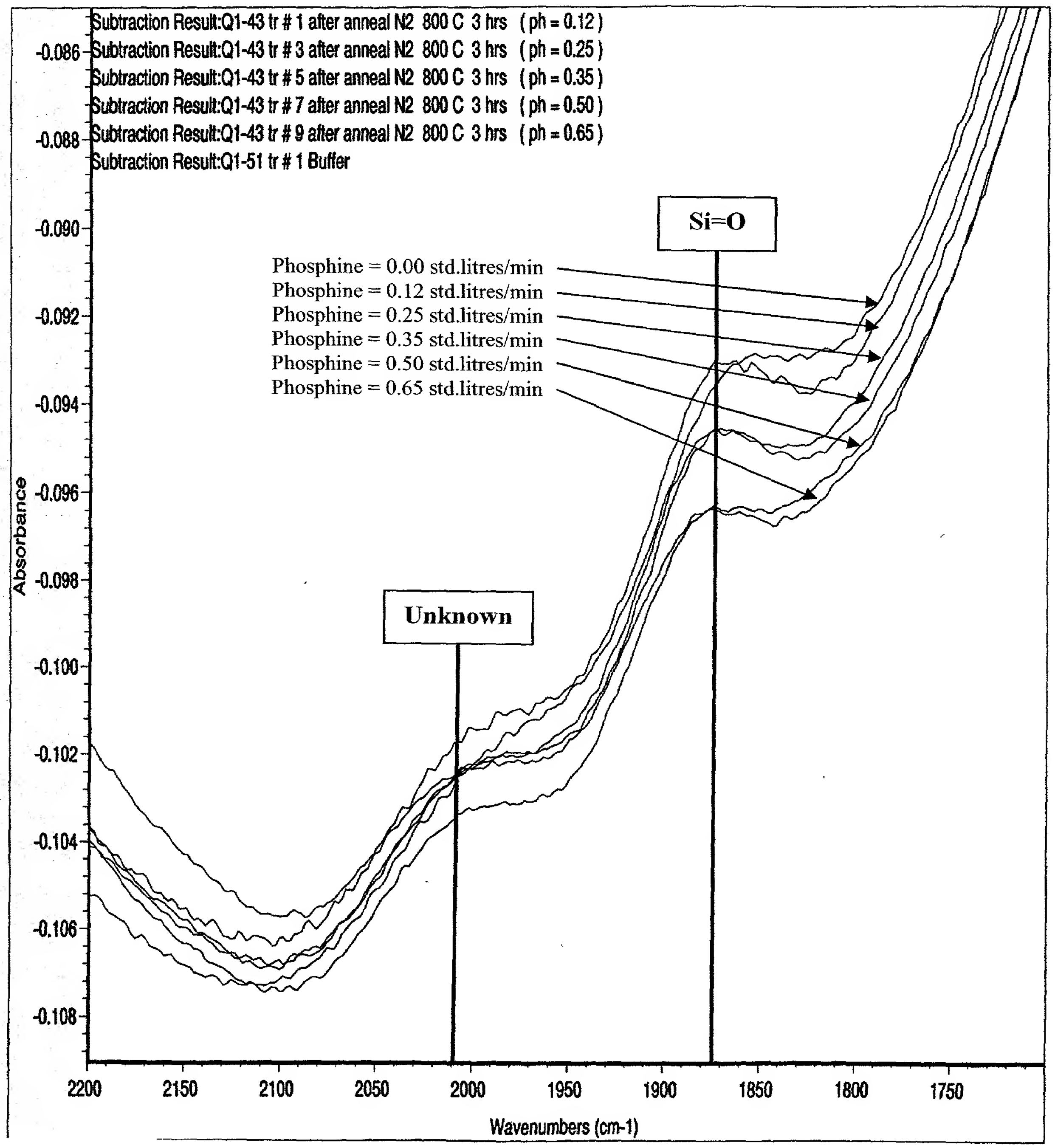
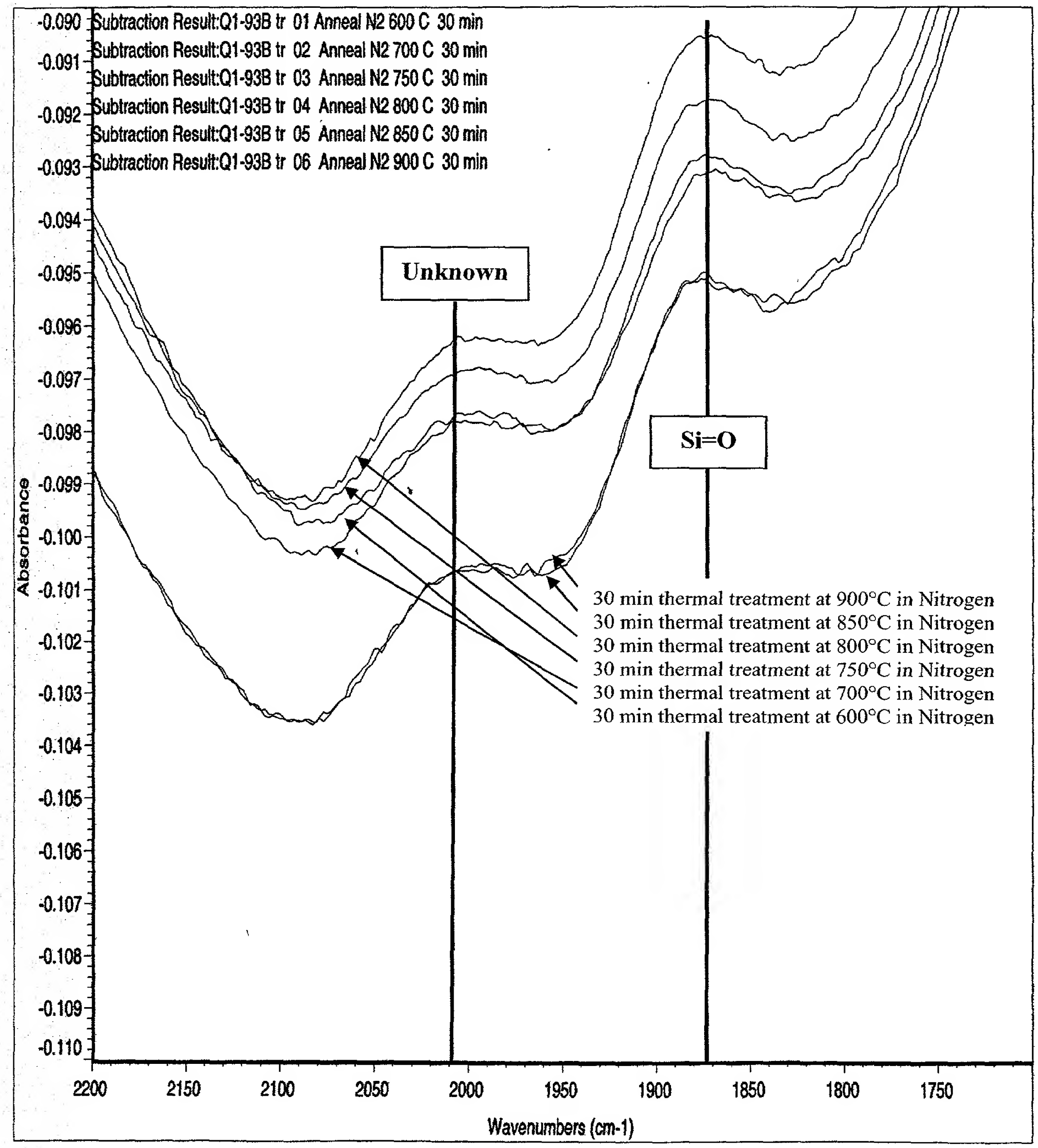
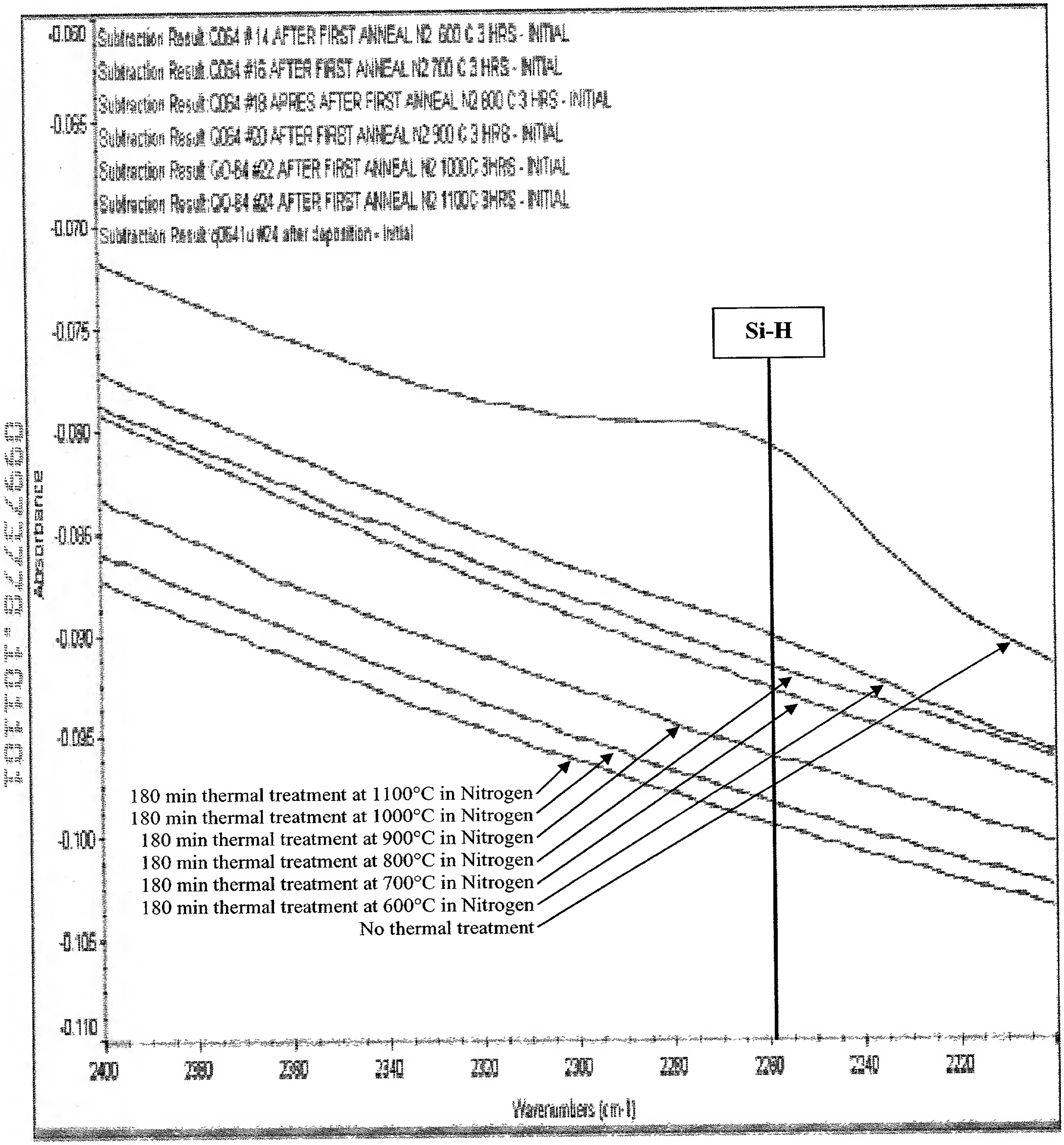

Subtraction Result:Q1-43 tr # 1 after anneal N2 800 C 3 hrs (ph = 0.12)
Subtraction Result:Q1-43 tr # 3 after anneal N2 800 C 3 hrs (ph = 0.25)
Subtraction Result:Q1-43 tr # 5 after anneal N2 800 C 3 hrs (ph = 0.35)
Subtraction Result:Q1-43 tr # 7 after anneal N2 800 C 3 hrs (ph = 0.50)
Subtraction Result:Q1-43 tr # 9 after anneal N2 800 C 3 hrs (ph = 0.65)
Subtraction Result:Q1-51 tr # 1 Buffer
Si=O
Phosphine = 0.00 std.litres/min
Phosphine = 0.12 std.litres/min
Phosphine = 0.25 std.litres/min
Phosphine = 0.35 std.litres/min
Phosphine = 0.50 std.litres/min
Phosphine = 0.65 std.litres/min
Unknown
Absorbance
-0.086
-0.088
-0.090
-0.092
-0.094
-0.096
-0.098
-0.100
-0.102
-0.104
-0.106
-0.108
2200
2150
2100
2050
2000
1950
1900
1850
1800
1750
Wavenumbers (cm-1)

Figure 7d



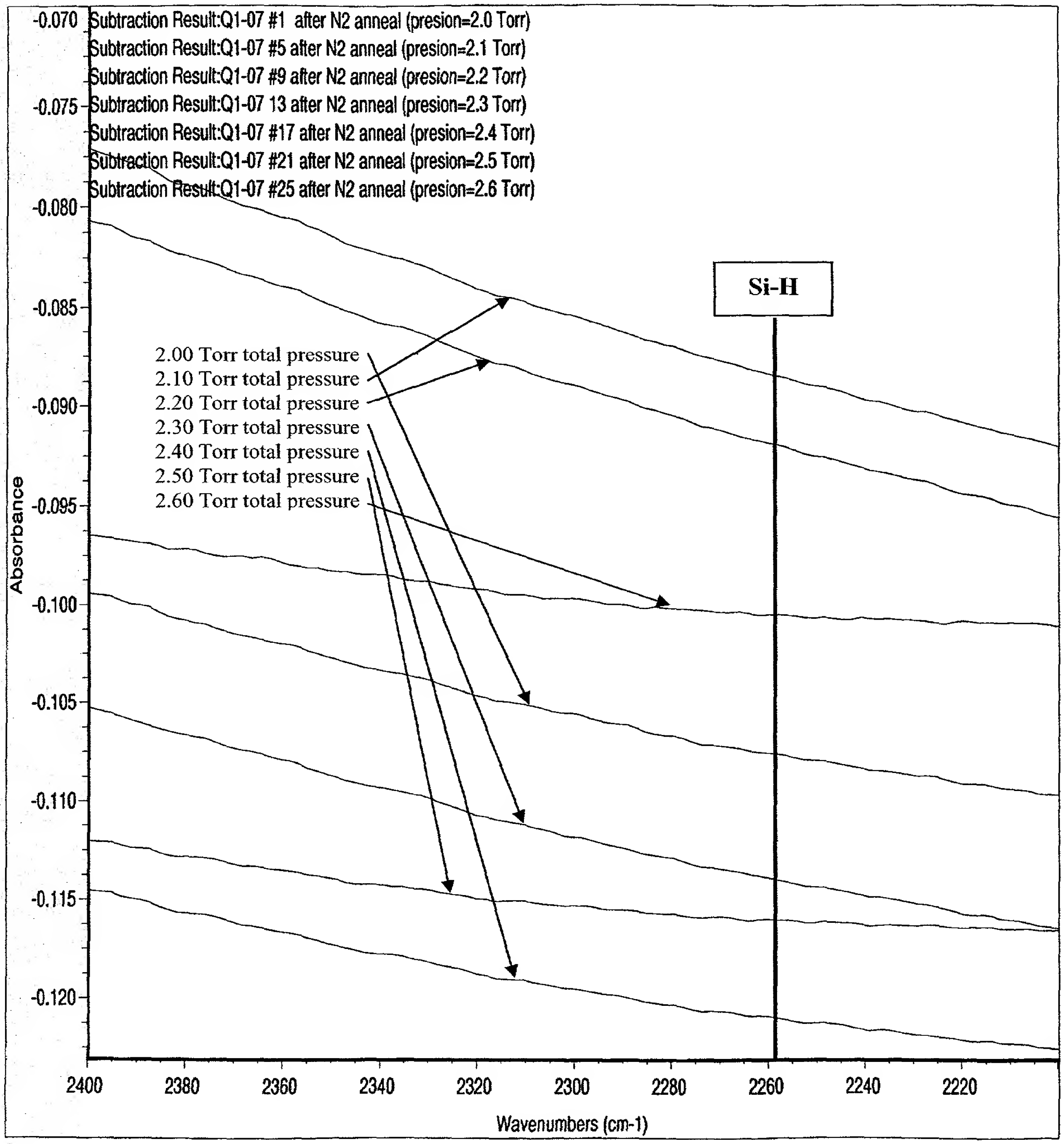
Subtraction Result:Q1-93B tr 01 Anneal N2 600 C 30 min
Subtraction Result:Q1-93B tr 02 Anneal N2 700 C 30 min
Subtraction Result:Q1-93B tr 03 Anneal N2 750 C 30 min
Subtraction Result:Q1-93B tr 04 Anneal N2 800 C 30 min
Subtraction Result:Q1-93B tr 05 Anneal N2 850 C 30 min
Subtraction Result:Q1-93B tr 06 Anneal N2 900 C 30 min
Unknown
Si=O
30 min thermal treatment at 900°C in Nitrogen
30 min thermal treatment at 850°C in Nitrogen
30 min thermal treatment at 800°C in Nitrogen
30 min thermal treatment at 750°C in Nitrogen
30 min thermal treatment at 700°C in Nitrogen
30 min thermal treatment at 600°C in Nitrogen
Absorbance
-0.090
-0.091
-0.092
-0.093
-0.094
-0.095
-0.096
-0.097
-0.098
-0.099
-0.100
-0.101
-0.102
-0.103
-0.104
-0.105
-0.106
-0.107
-0.108
-0.109
-0.110
2200
2150
2100
2050
2000
1950
1900
1850
1800
1750
Wavenumbers (cm-1)

Figure 8a



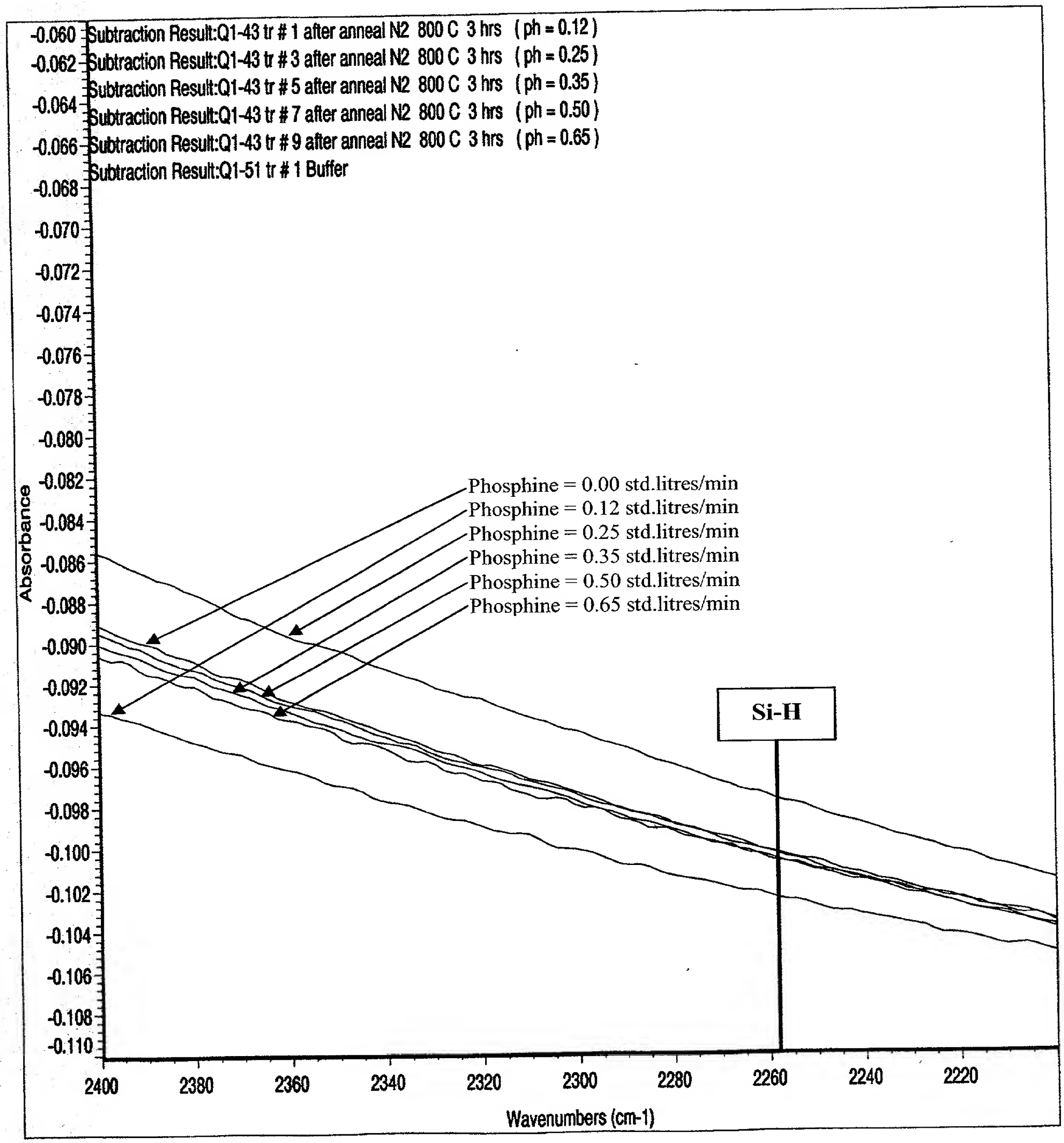
Subtraction Result:C064 #14 AFTER FIRST ANNEAL N2 600 C 3 HRS - INITIAL
Subtraction Result:C064 #16 AFTER FIRST ANNEAL N2 700 C 3 HRS - INITIAL
Subtraction Result:C064 #18 APRES AFTER FIRST ANNEAL N2 800 C 3 HRS - INITIAL
Subtraction Result:C064 #20 AFTER FIRST ANNEAL N2 900 C 3 HRS - INITIAL
Subtraction Result:CO-64 #22 AFTER FIRST ANNEAL N2 1000C 3HRS - INITIAL
Subtraction Result:CO-64 #24 AFTER FIRST ANNEAL N2 1100C 3HRS - INITIAL
Subtraction Result:c0641u #24 after deposition - initial
Si-H
180 min thermal treatment at 1100°C in Nitrogen
180 min thermal treatment at 1000°C in Nitrogen
180 min thermal treatment at 900°C in Nitrogen
180 min thermal treatment at 800°C in Nitrogen
180 min thermal treatment at 700°C in Nitrogen
180 min thermal treatment at 600°C in Nitrogen
No thermal treatment
Absorbance
-0.060
-0.065
-0.070
-0.075
-0.080
-0.085
-0.090
-0.095
-0.100
-0.105
-0.110
2400
2380
2360
2340
2320
2300
2280
2260
2240
2220
Wavenumbers (cm-1)

Figure 8b



Subtraction Result:Q1-07 #1 after N2 anneal (presion=2.0 Torr)
Subtraction Result:Q1-07 #5 after N2 anneal (presion=2.1 Torr)
Subtraction Result:Q1-07 #9 after N2 anneal (presion=2.2 Torr)
Subtraction Result:Q1-07 13 after N2 anneal (presion=2.3 Torr)
Subtraction Result:Q1-07 #17 after N2 anneal (presion=2.4 Torr)
Subtraction Result:Q1-07 #21 after N2 anneal (presion=2.5 Torr)
Subtraction Result:Q1-07 #25 after N2 anneal (presion=2.6 Torr)
Si-H
2.00 Torr total pressure
2.10 Torr total pressure
2.20 Torr total pressure
2.30 Torr total pressure
2.40 Torr total pressure
2.50 Torr total pressure
2.60 Torr total pressure
-0.070
-0.075
-0.080
-0.085
-0.090
-0.095
-0.100
-0.105
-0.110
-0.115
-0.120
Absorbance
2400
2380
2360
2340
2320
2300
2280
2260
2240
2220
Wavenumbers (cm-1)

Figure 8c



Subtraction Result:Q1-43 tr # 1 after anneal N2 800 C 3 hrs (ph = 0.12)
Subtraction Result:Q1-43 tr # 3 after anneal N2 800 C 3 hrs (ph = 0.25)
Subtraction Result:Q1-43 tr # 5 after anneal N2 800 C 3 hrs (ph = 0.35)
Subtraction Result:Q1-43 tr # 7 after anneal N2 800 C 3 hrs (ph = 0.50)
Subtraction Result:Q1-43 tr # 9 after anneal N2 800 C 3 hrs (ph = 0.65)
Subtraction Result:Q1-51 tr # 1 Buffer
Phosphine = 0.00 std.litres/min
Phosphine = 0.12 std.litres/min
Phosphine = 0.25 std.litres/min
Phosphine = 0.35 std.litres/min
Phosphine = 0.50 std.litres/min
Phosphine = 0.65 std.litres/min
Si-H
Absorbance
Wavenumbers (cm-1)
-0.060
-0.062
-0.064
-0.066
-0.068
-0.070
-0.072
-0.074
-0.076
-0.078
-0.080
-0.082
-0.084
-0.086
-0.088
-0.090
-0.092
-0.094
-0.096
-0.098
-0.100
-0.102
-0.104
-0.106
-0.108
-0.110
2400
2380
2360
2340
2320
2300
2280
2260
2240
2220

Figure 8d

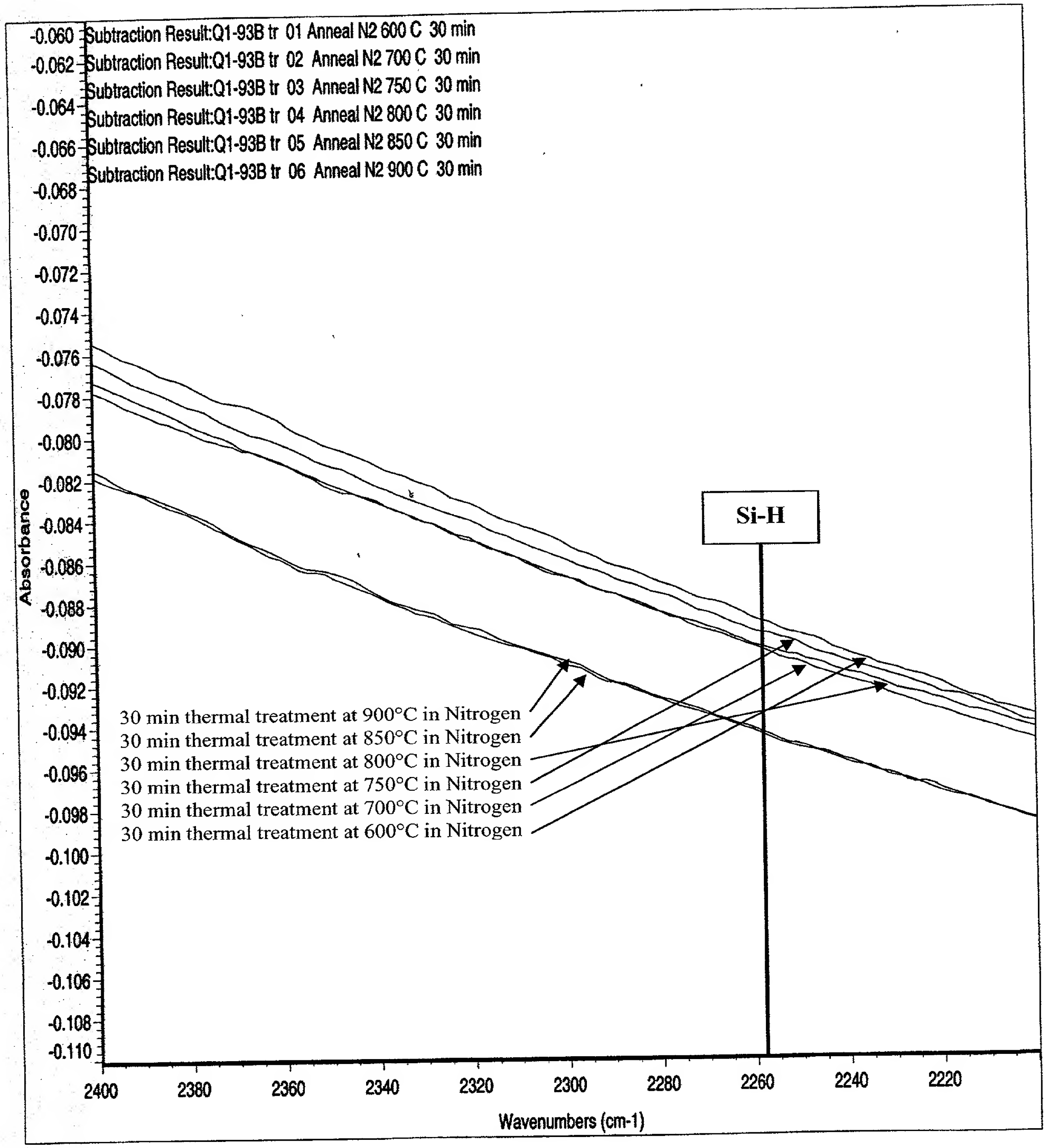

Subtraction Result:Q1-93B tr 01 Anneal N2 600 C 30 min
Subtraction Result:Q1-93B tr 02 Anneal N2 700 C 30 min
Subtraction Result:Q1-93B tr 03 Anneal N2 750 C 30 min
Subtraction Result:Q1-93B tr 04 Anneal N2 800 C 30 min
Subtraction Result:Q1-93B tr 05 Anneal N2 850 C 30 min
Subtraction Result:Q1-93B tr 06 Anneal N2 900 C 30 min
Si-H
30 min thermal treatment at 900°C in Nitrogen
30 min thermal treatment at 850°C in Nitrogen
30 min thermal treatment at 800°C in Nitrogen
30 min thermal treatment at 750°C in Nitrogen
30 min thermal treatment at 700°C in Nitrogen
30 min thermal treatment at 600°C in Nitrogen
Absorbance
Wavenumbers (cm-1)
-0.060
-0.062
-0.064
-0.066
-0.068
-0.070
-0.072
-0.074
-0.076
-0.078
-0.080
-0.082
-0.084
-0.086
-0.088
-0.090
-0.092
-0.094
-0.096
-0.098
-0.100
-0.102
-0.104
-0.106
-0.108
-0.110
2400
2380
2360
2340
2320
2300
2280
2260
2240
2220

Figure 9a

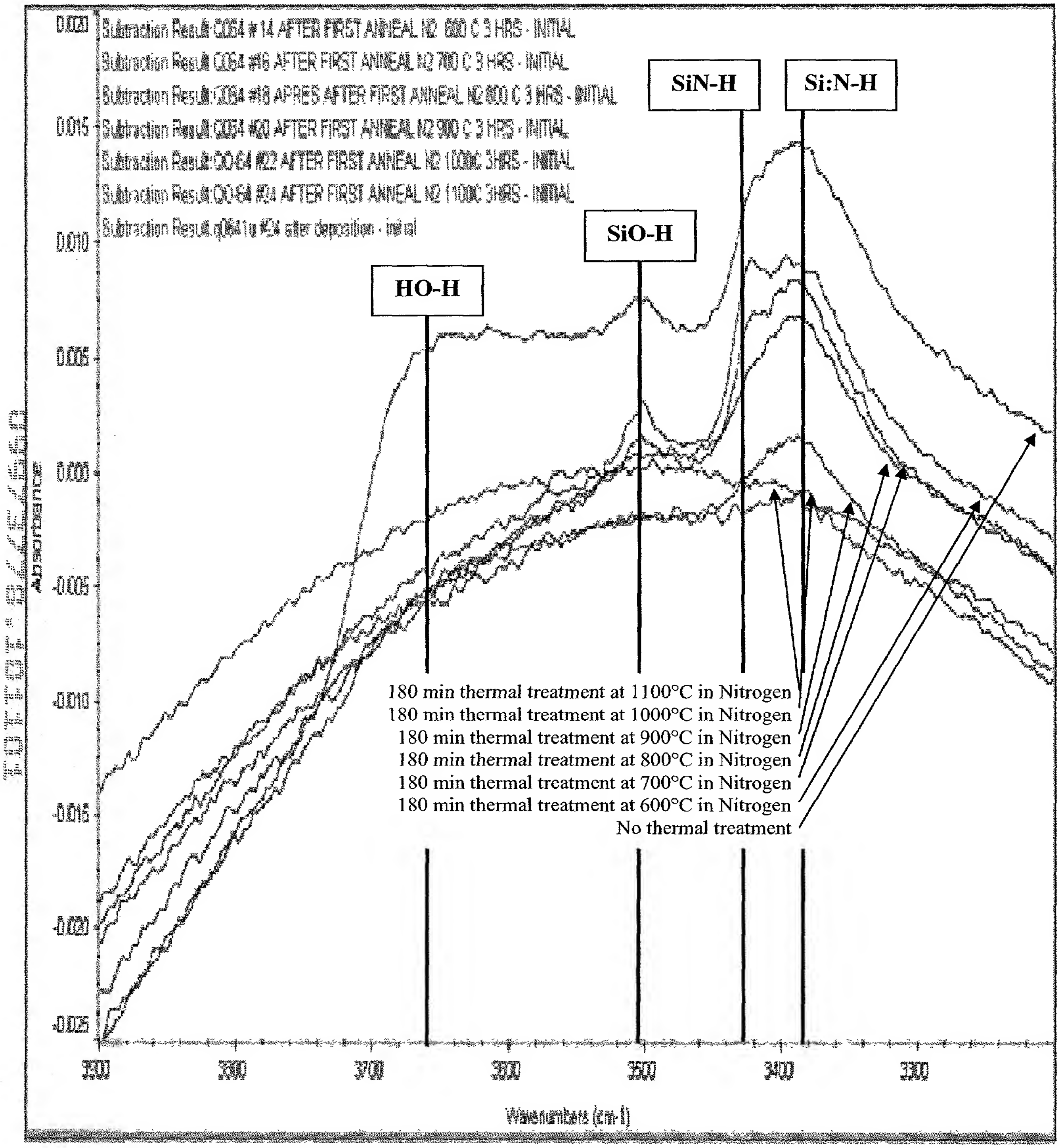

Subtraction Result:Q054 #14 AFTER FIRST ANNEAL N2 600 C 3 HRS - INITIAL
Subtraction Result:Q054 #16 AFTER FIRST ANNEAL N2 700 C 3 HRS - INITIAL
Subtraction Result:Q054 #18 APRES AFTER FIRST ANNEAL N2 800 C 3 HRS - INITIAL
Subtraction Result:Q054 #20 AFTER FIRST ANNEAL N2 900 C 3 HRS - INITIAL
Subtraction Result:QO-54 #22 AFTER FIRST ANNEAL N2 1000C 3HRS - INITIAL
Subtraction Result:QO-54 #24 AFTER FIRST ANNEAL N2 1100C 3HRS - INITIAL
Subtraction Result:q0541u #24 after deposition - initial
SiN-H
Si:N-H
SiO-H
HO-H
180 min thermal treatment at 1100°C in Nitrogen
180 min thermal treatment at 1000°C in Nitrogen
180 min thermal treatment at 900°C in Nitrogen
180 min thermal treatment at 800°C in Nitrogen
180 min thermal treatment at 700°C in Nitrogen
180 min thermal treatment at 600°C in Nitrogen
No thermal treatment
Absorbance
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
3900
3800
3700
3600
3500
3400
3300
Wavenumbers (cm-1)

Figure 9b

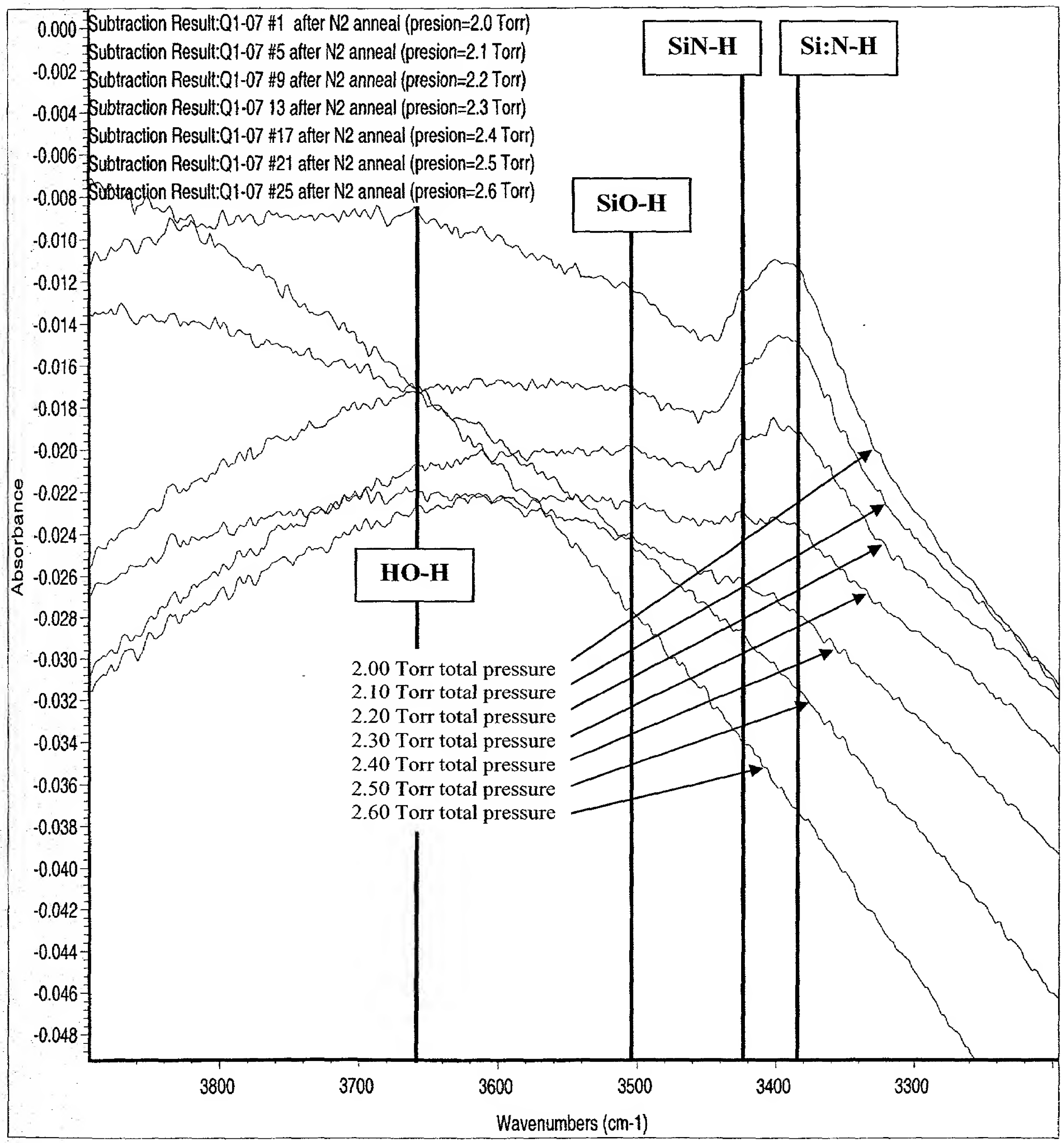
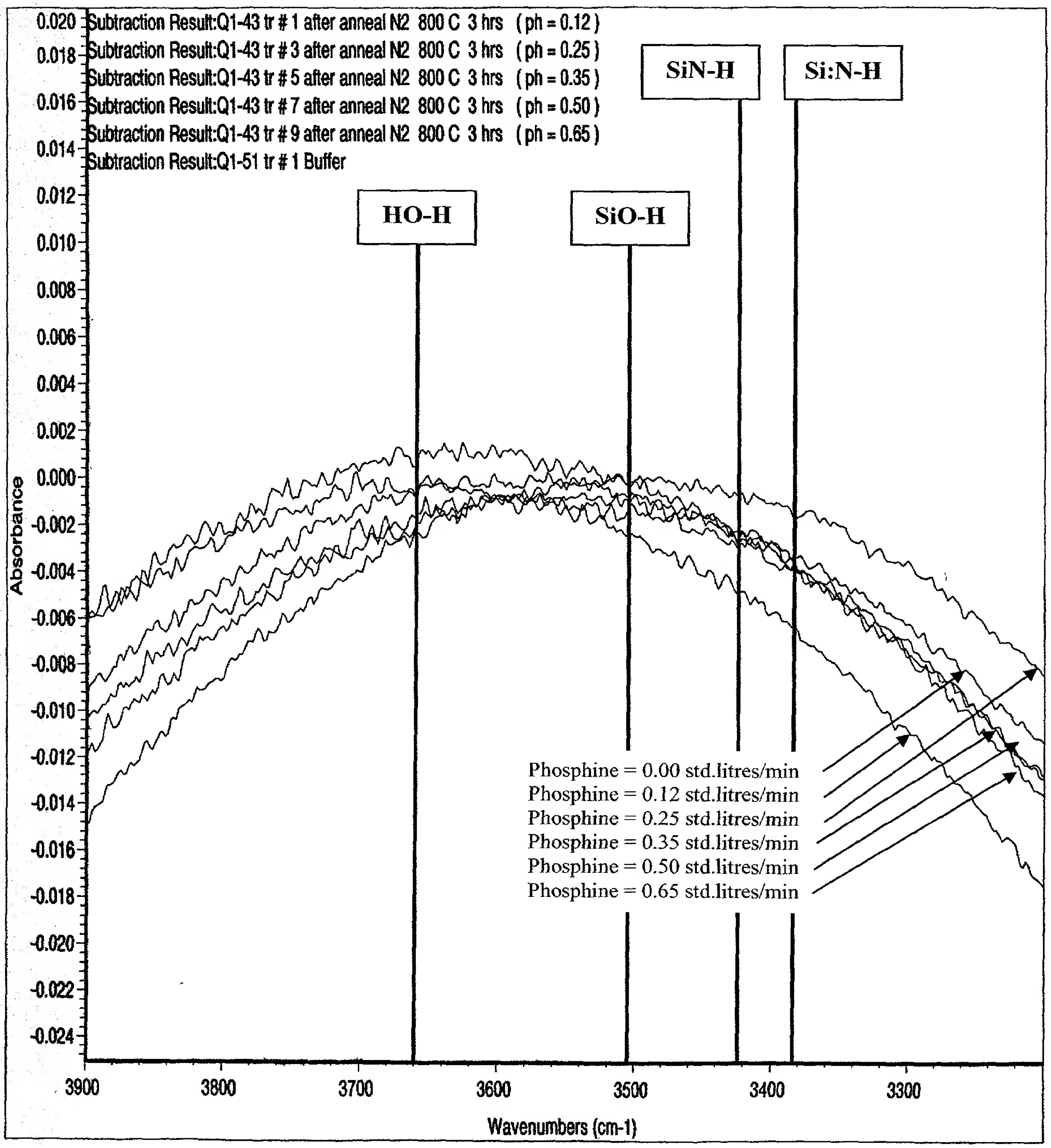

Subtraction Result:Q1-07 #1 after N2 anneal (presion=2.0 Torr)
Subtraction Result:Q1-07 #5 after N2 anneal (presion=2.1 Torr)
Subtraction Result:Q1-07 #9 after N2 anneal (presion=2.2 Torr)
Subtraction Result:Q1-07 13 after N2 anneal (presion=2.3 Torr)
Subtraction Result:Q1-07 #17 after N2 anneal (presion=2.4 Torr)
Subtraction Result:Q1-07 #21 after N2 anneal (presion=2.5 Torr)
Subtraction Result:Q1-07 #25 after N2 anneal (presion=2.6 Torr)
SiN-H
Si:N-H
SiO-H
HO-H
2.00 Torr total pressure
2.10 Torr total pressure
2.20 Torr total pressure
2.30 Torr total pressure
2.40 Torr total pressure
2.50 Torr total pressure
2.60 Torr total pressure
Absorbance
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
-0.012
-0.014
-0.016
-0.018
-0.020
-0.022
-0.024
-0.026
-0.028
-0.030
-0.032
-0.034
-0.036
-0.038
-0.040
-0.042
-0.044
-0.046
-0.048
3800
3700
3600
3500
3400
3300
Wavenumbers (cm-1)

Figure 9c



Subtraction Result:Q1-43 tr # 1 after anneal N2 800 C 3 hrs (ph = 0.12)
Subtraction Result:Q1-43 tr # 3 after anneal N2 800 C 3 hrs (ph = 0.25)
Subtraction Result:Q1-43 tr # 5 after anneal N2 800 C 3 hrs (ph = 0.35)
Subtraction Result:Q1-43 tr # 7 after anneal N2 800 C 3 hrs (ph = 0.50)
Subtraction Result:Q1-43 tr # 9 after anneal N2 800 C 3 hrs (ph = 0.65)
Subtraction Result:Q1-51 tr # 1 Buffer
SiN-H
Si:N-H
HO-H
SiO-H
Phosphine = 0.00 std.litres/min
Phosphine = 0.12 std.litres/min
Phosphine = 0.25 std.litres/min
Phosphine = 0.35 std.litres/min
Phosphine = 0.50 std.litres/min
Phosphine = 0.65 std.litres/min
Absorbance
Wavenumbers (cm-1)
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
-0.012
-0.014
-0.016
-0.018
-0.020
-0.022
-0.024
3900
3800
3700
3600
3500
3400
3300

Figure 9d

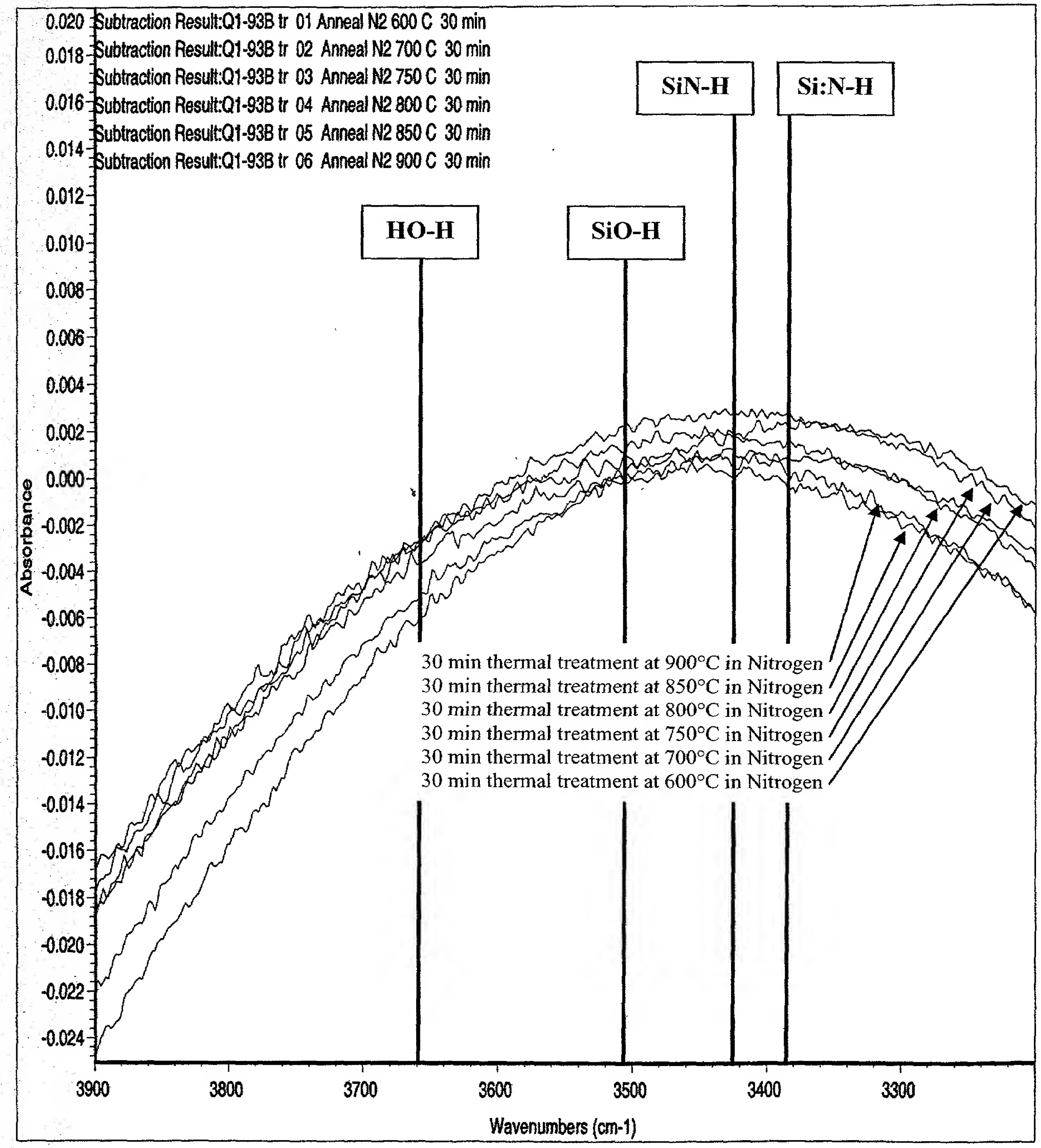
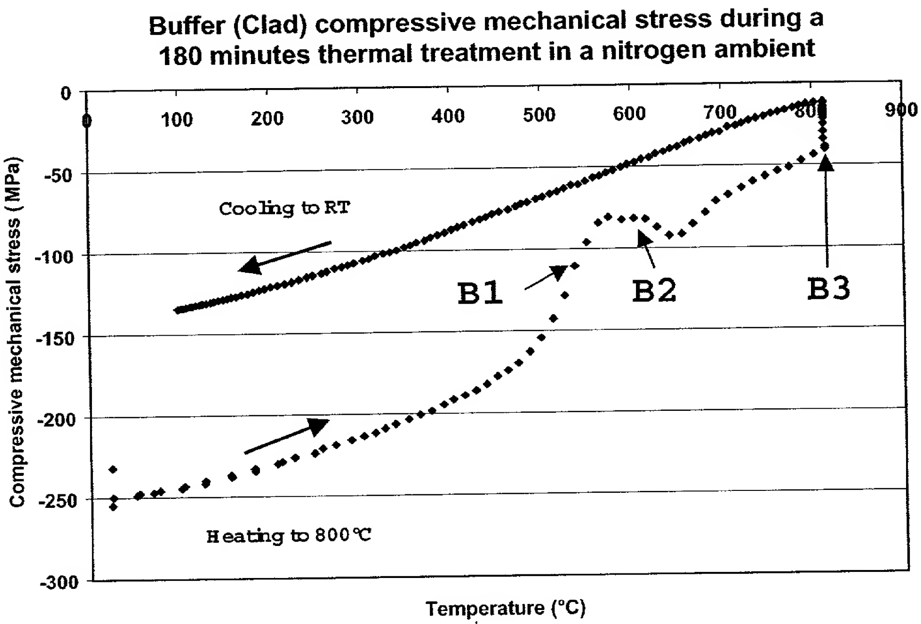
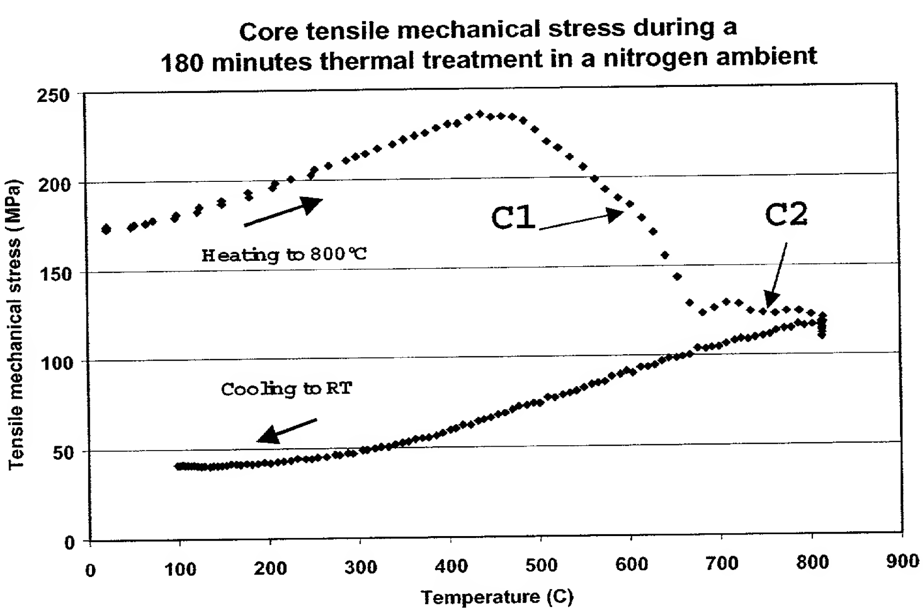

Subtraction Result:Q1-93B tr 01 Anneal N2 600 C 30 min
Subtraction Result:Q1-93B tr 02 Anneal N2 700 C 30 min
Subtraction Result:Q1-93B tr 03 Anneal N2 750 C 30 min
Subtraction Result:Q1-93B tr 04 Anneal N2 800 C 30 min
Subtraction Result:Q1-93B tr 05 Anneal N2 850 C 30 min
Subtraction Result:Q1-93B tr 06 Anneal N2 900 C 30 min
SiN-H
Si:N-H
HO-H
SiO-H
30 min thermal treatment at 900°C in Nitrogen
30 min thermal treatment at 850°C in Nitrogen
30 min thermal treatment at 800°C in Nitrogen
30 min thermal treatment at 750°C in Nitrogen
30 min thermal treatment at 700°C in Nitrogen
30 min thermal treatment at 600°C in Nitrogen
Absorbance
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
-0.012
-0.014
-0.016
-0.018
-0.020
-0.022
-0.024
3900
3800
3700
3600
3500
3400
3300
Wavenumbers (cm-1)

Figure 10



Buffer (Clad) compressive mechanical stress during a 180 minutes thermal treatment in a nitrogen ambient
Compressive mechanical stress (MPa)
0
-50
-100
-150
-200
-250
-300
0
100
200
300
400
500
600
700
800
900
Cooling to RT
Heating to 800°C
B1
B2
B3
Temperature (°C)



Core tensile mechanical stress during a 180 minutes thermal treatment in a nitrogen ambient
Tensile mechanical stress (MPa)
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
Heating to 800°C
Cooling to RT
C1
C2
Temperature (C)

Figure 11

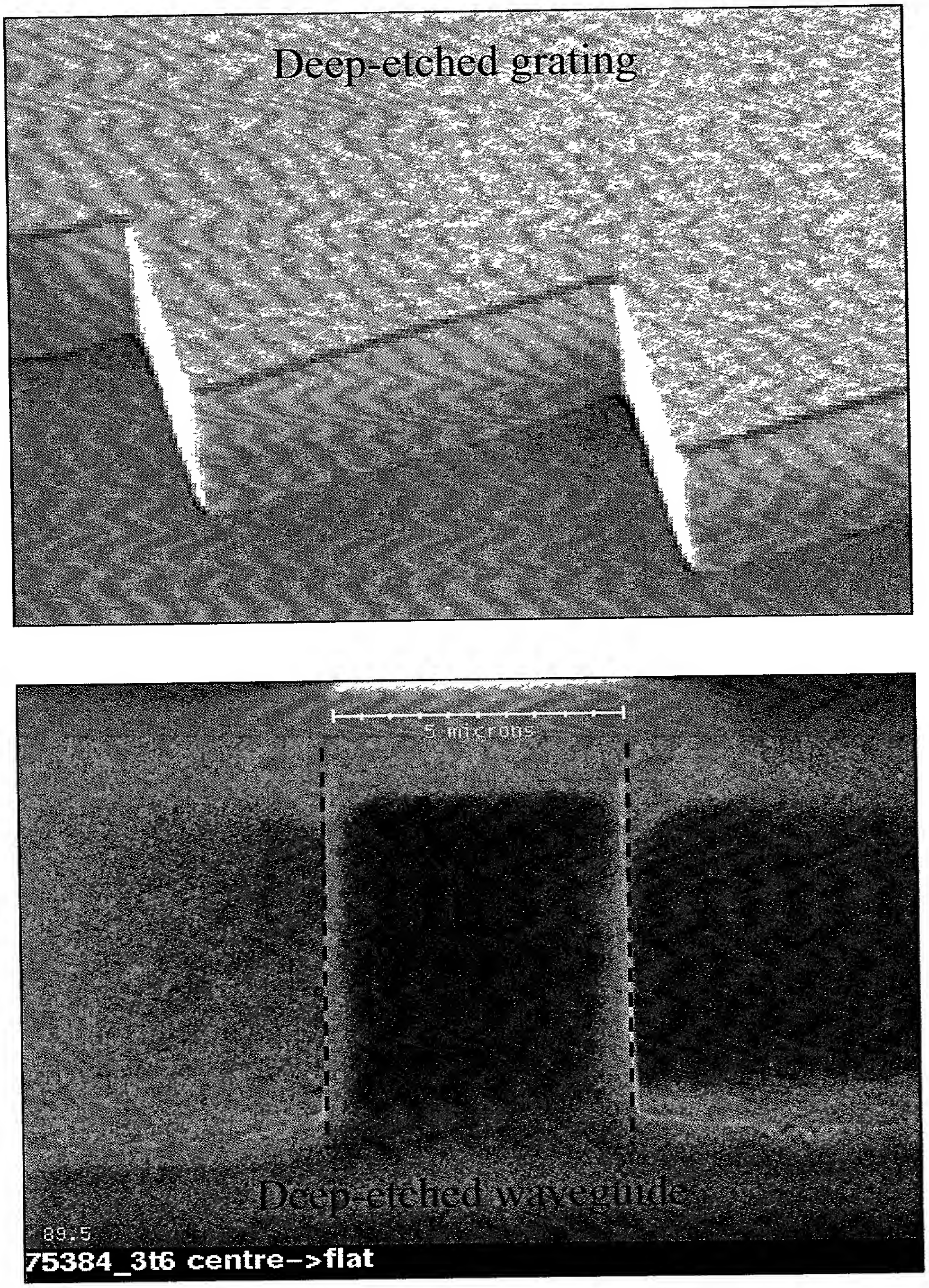

Deep-etched grating
5 microns
Deep-etched waveguide
89.5
75384_3t6 centre->flat

Figure 12

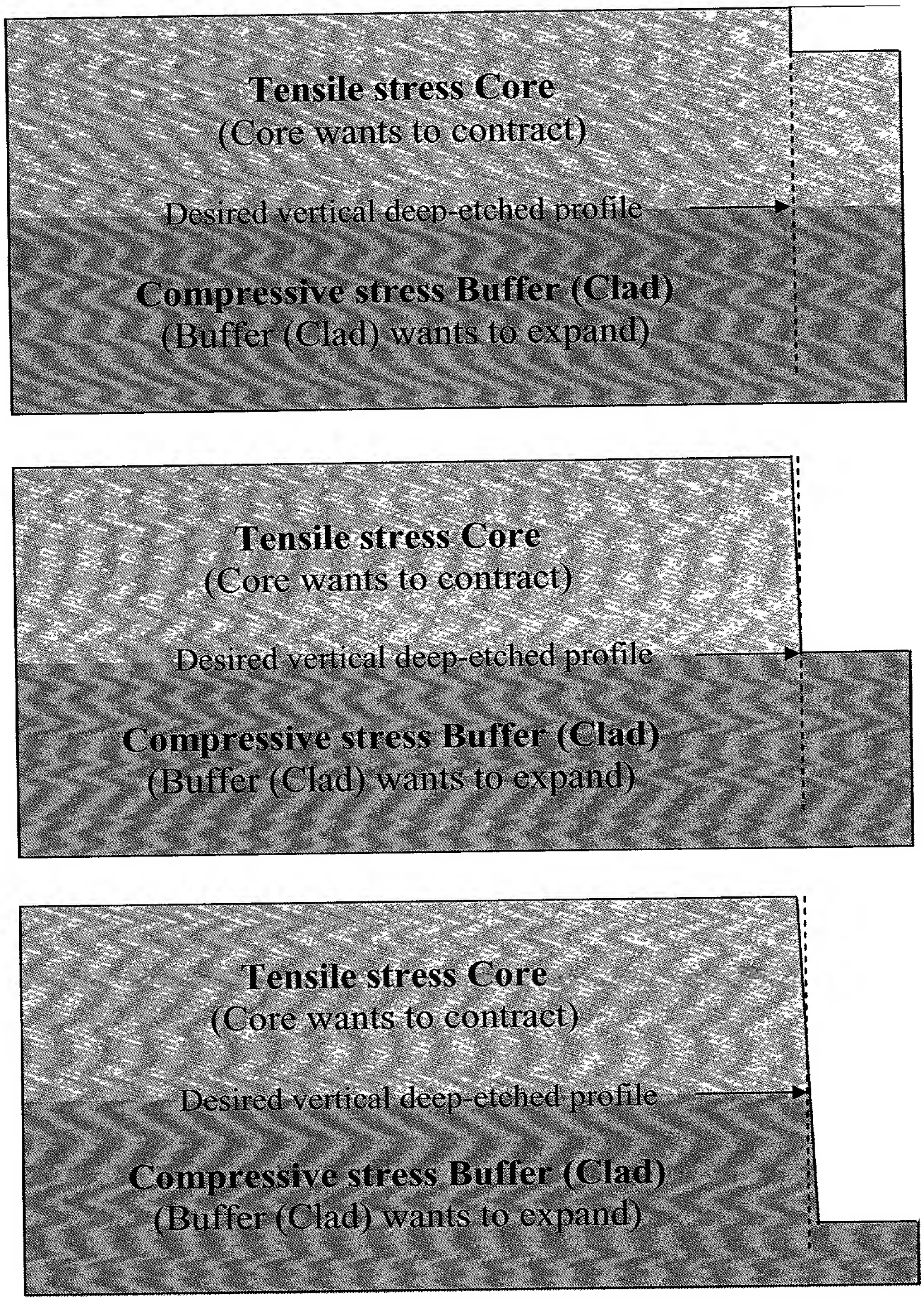
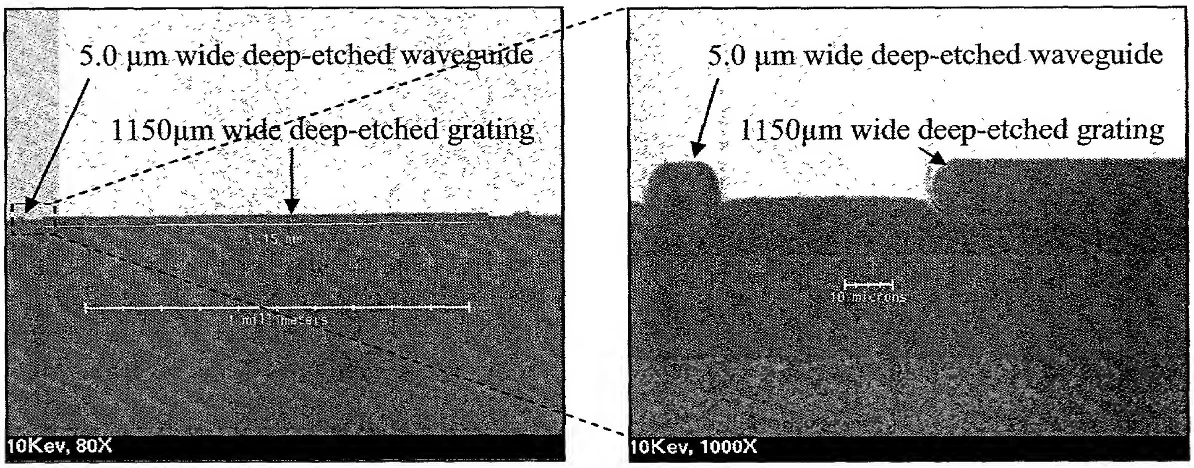
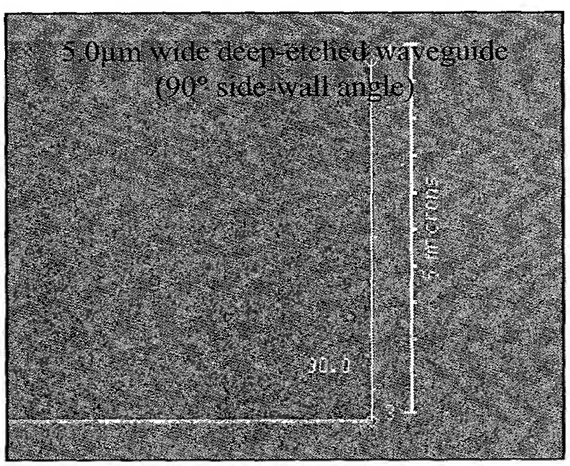

Tensile stress Core
(Core wants to contract)
Desired vertical deep-etched profile
Compressive stress Buffer (Clad)
(Buffer (Clad) wants to expand)
Tensile stress Core
(Core wants to contract)
Desired vertical deep-etched profile
Compressive stress Buffer (Clad)
(Buffer (Clad) wants to expand)
Tensile stress Core
(Core wants to contract)
Desired vertical deep-etched profile
Compressive stress Buffer (Clad)
(Buffer (Clad) wants to expand)

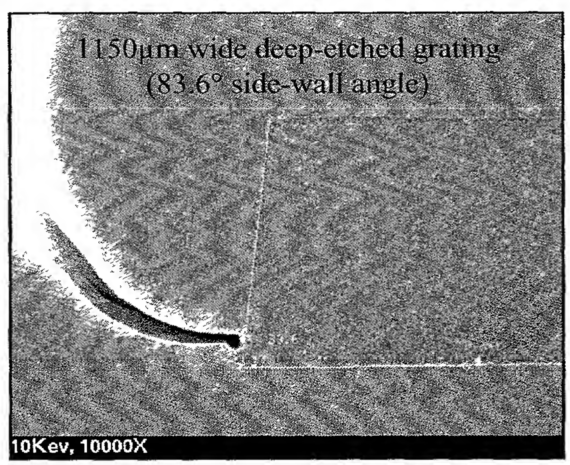
Figure 13



The relative position between an isolated 5.0µm wide deep-etched waveguide and its neighboring 1150µm wide deep-etched grating at two different magnifications.

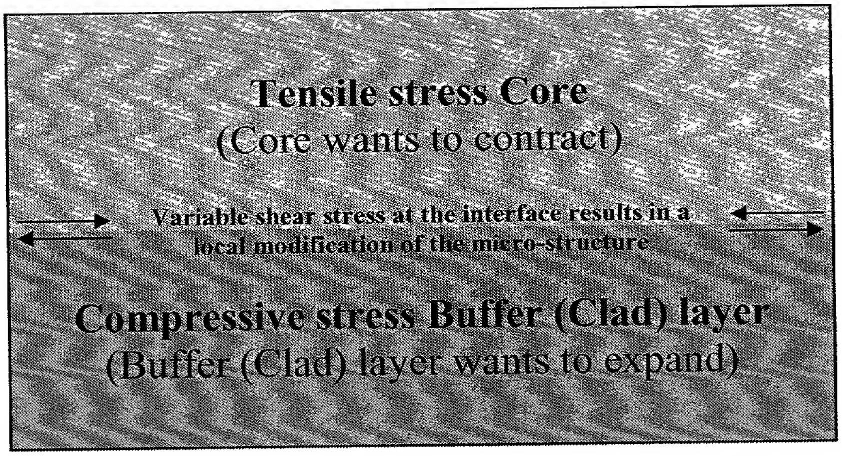


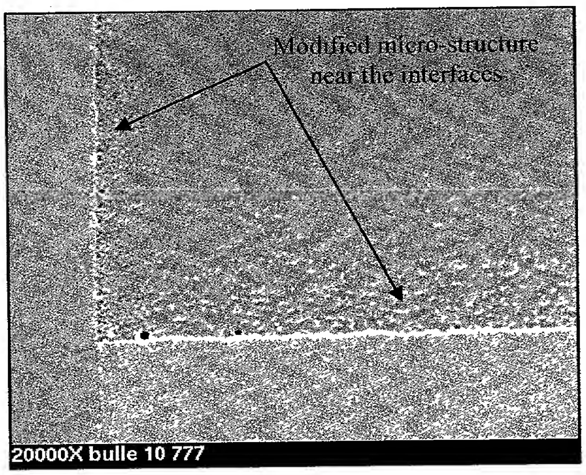
The side-wall of the 5.0µm wide deep-etched waveguide facing the neighboring grating has a slope of about 90°.



The side-wall of the 1150µm wide deep-etched grating facing the neighboring deep-etched waveguide has a much smaller slope of about 84°.

Figure 14


Tensile stress Core
(Core wants to contract)
Variable shear stress at the interface results in a local modification of the micro-structure
Compressive stress Buffer (Clad) layer
(Buffer (Clad) layer wants to expand)


Modified micro-structure near the interfaces
20000X bulle 10 777

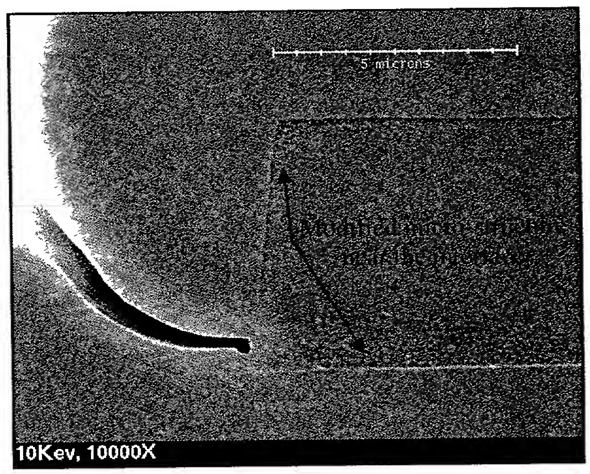
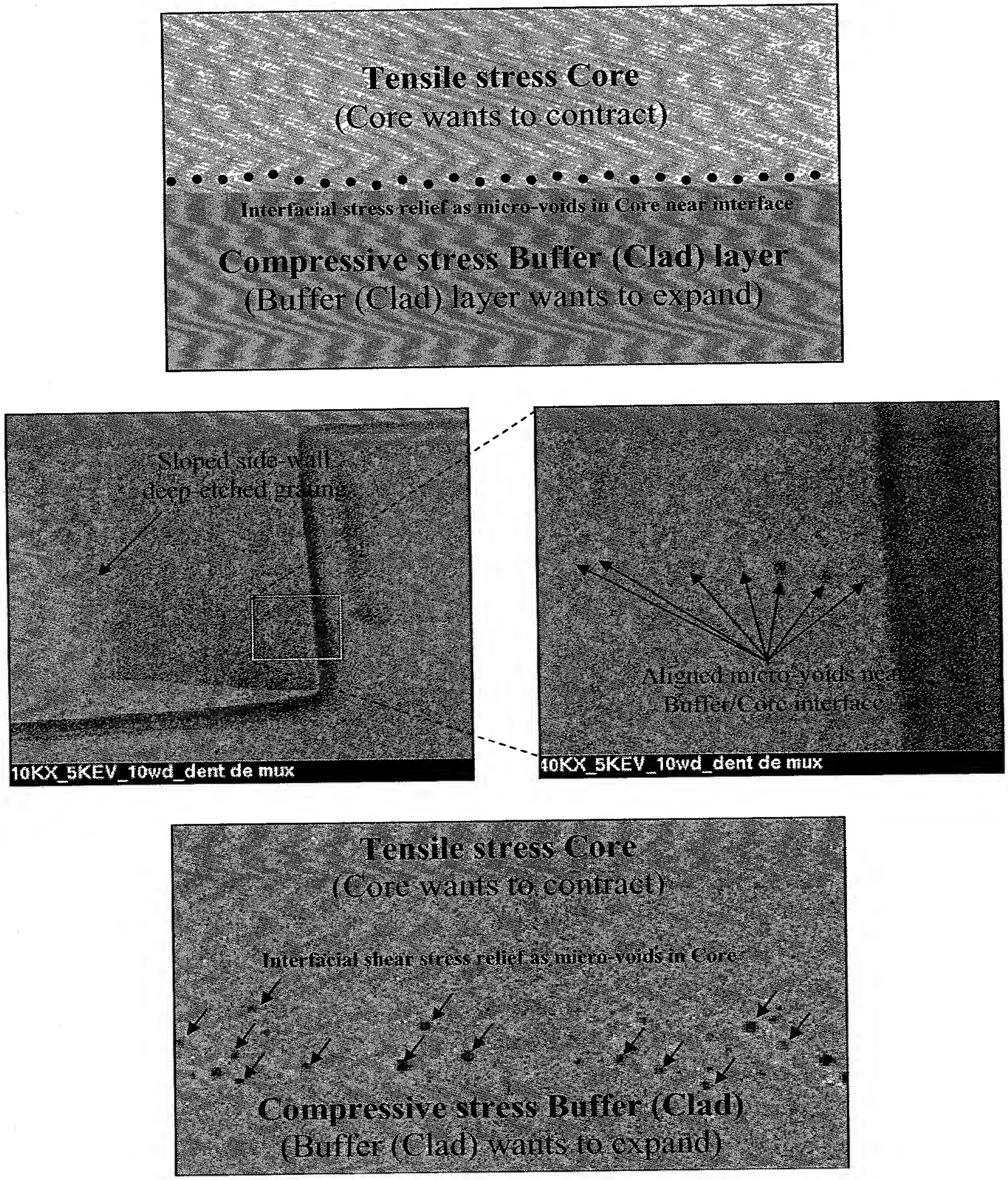
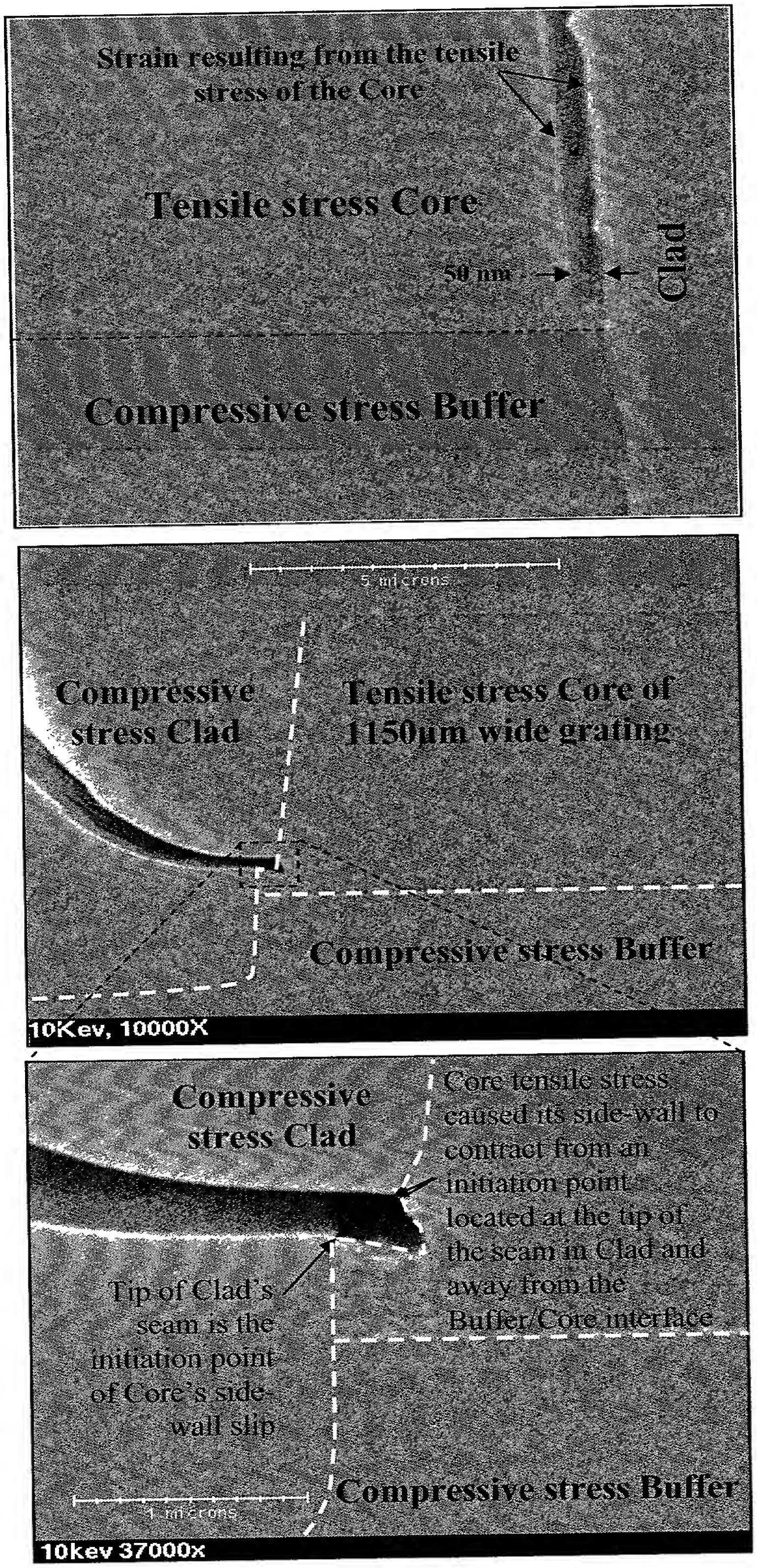

5 microns
10Kev, 10000X

Figure 15



Tensile stress Core
(Core wants to contract)
Interfacial stress relief as micro-voids in Core near interface
Compressive stress Buffer (Clad) layer
(Buffer (Clad) layer wants to expand)
Sloped side-wall
deep-etched grating
10KX_5KEV_10wd_dent de mux
Aligned micro-voids near
Buffer/Core interface
40KX_5KEV_10wd_dent de mux
Tensile stress Core
(Core wants to contract)
Interfacial shear stress relief as micro-voids in Core
Compressive stress Buffer (Clad)
(Buffer (Clad) wants to expand)

Figure 16



Strain resulting from the tensile stress of the Core
Tensile stress Core
50 nm
Clad
Compressive stress Buffer
5 microns
Compressive stress Clad
Tensile stress Core of 1150μm wide grating
Compressive stress Buffer
10Kev, 10000X
Compressive stress Clad
Core tensile stress caused its side-wall to contract from an initiation point located at the tip of the seam in Clad and away from the Buffer/Core interface
Tip of Clad's seam is the initiation point of Core's side-wall slip
Compressive stress Buffer
1 microns
10kev 37000x

Figure 17

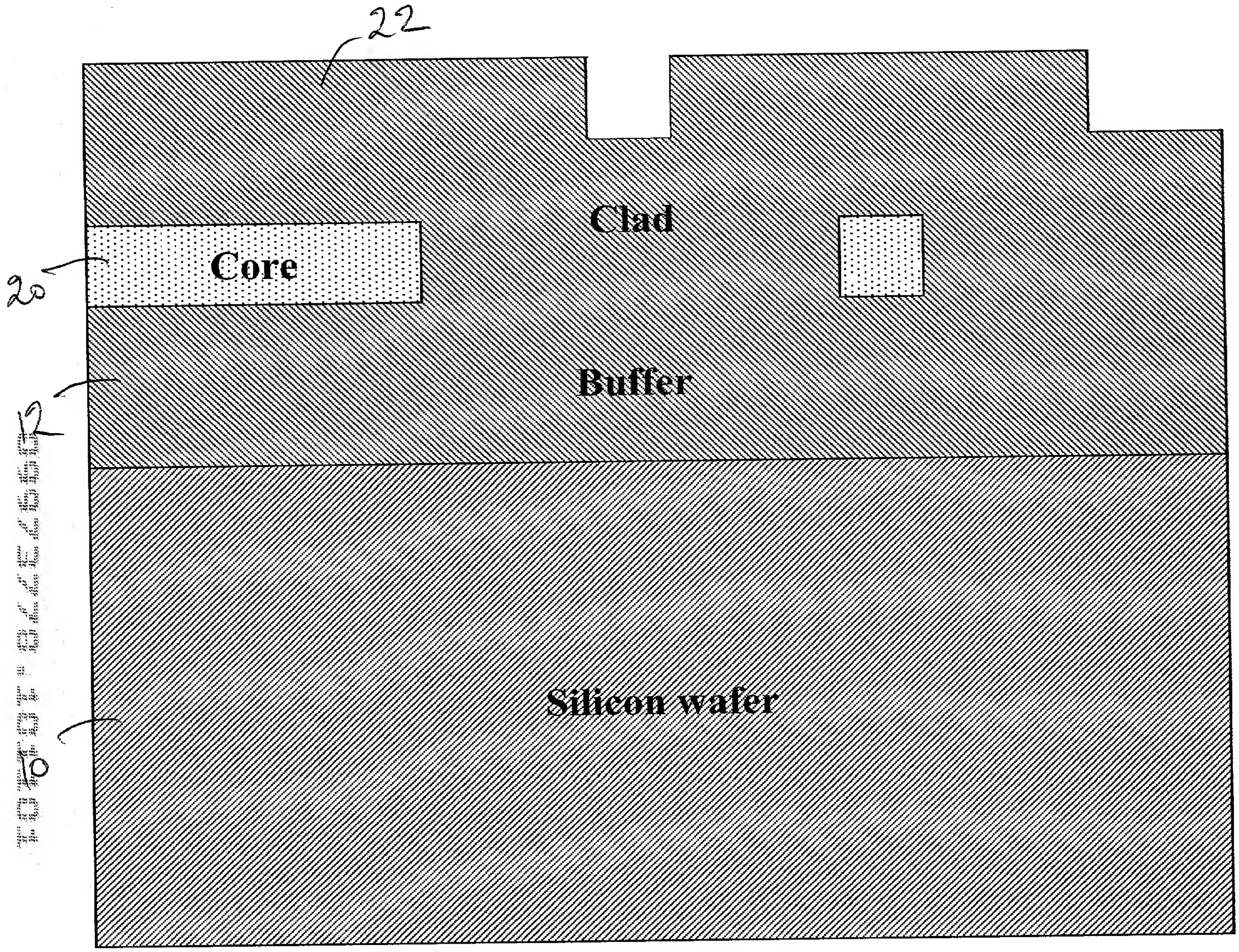


Figure 18a

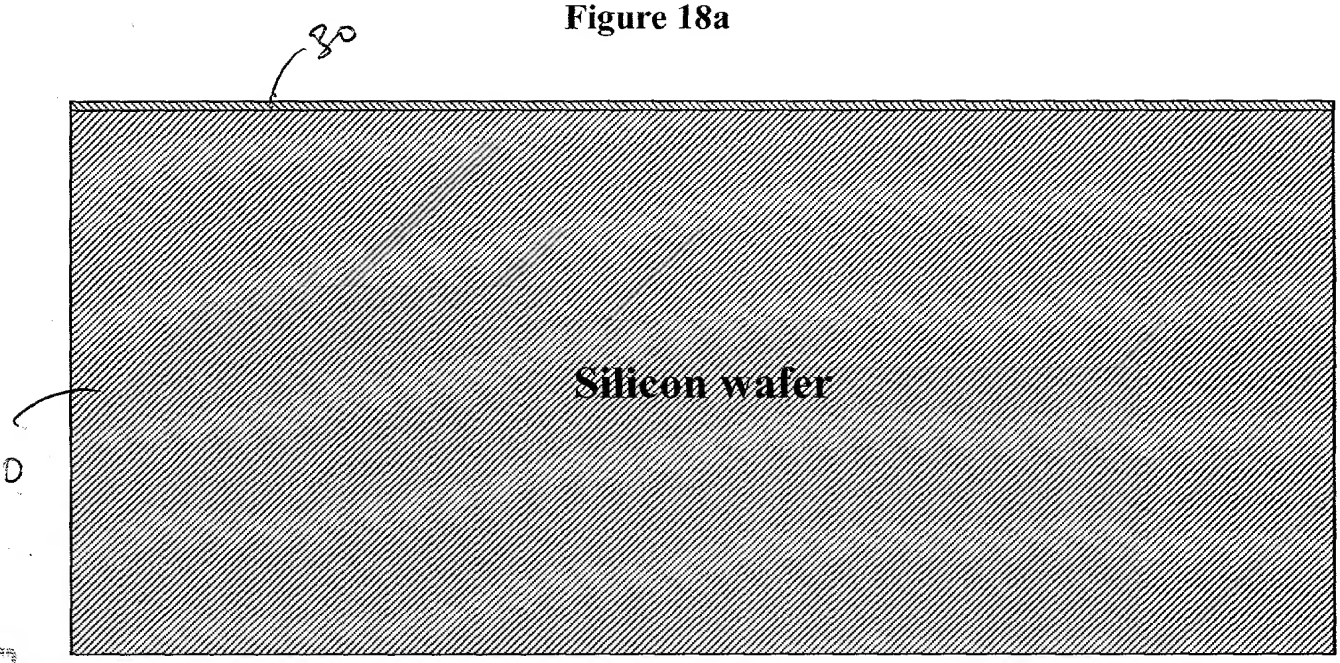


Figure 18b

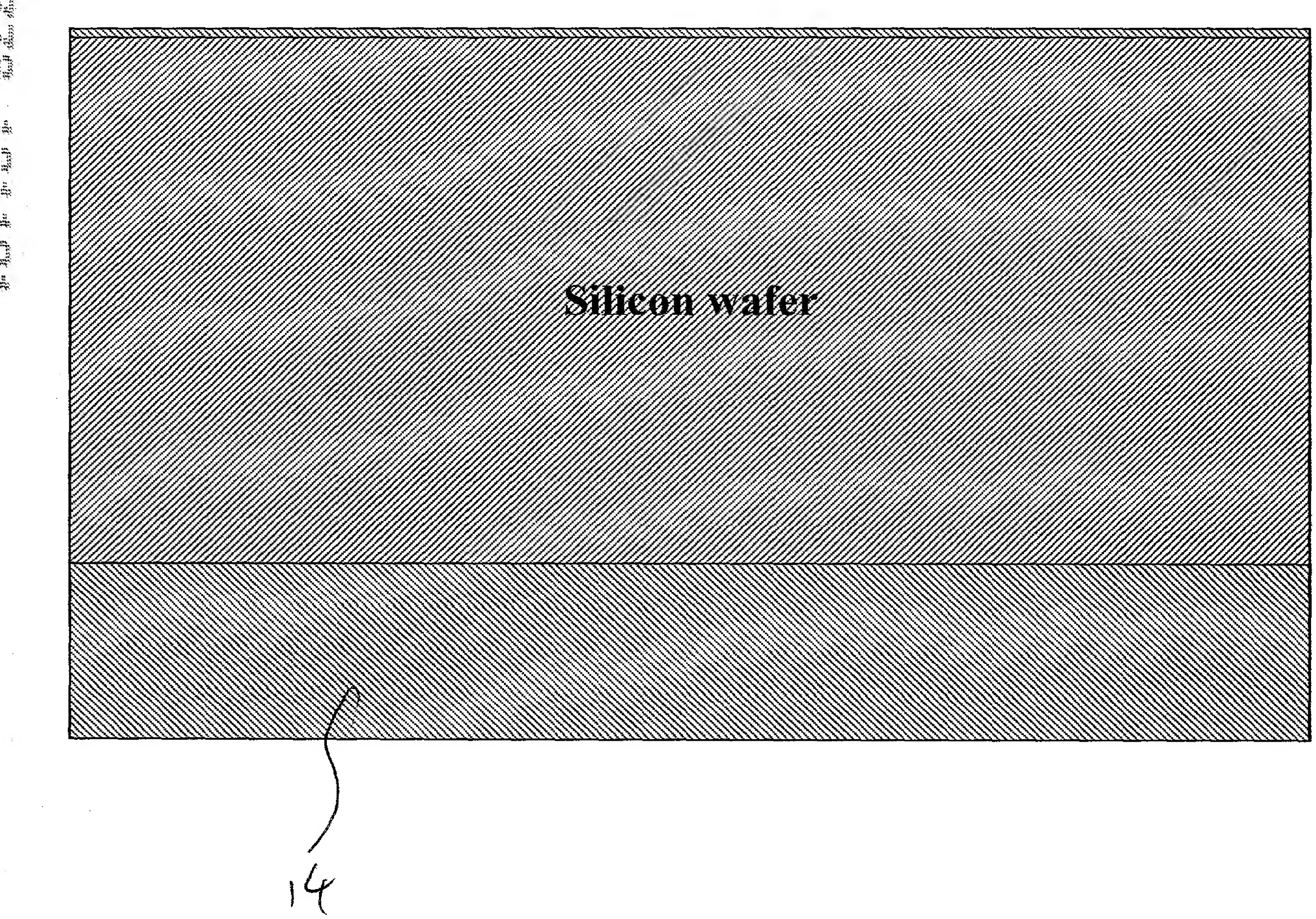


Figure 18c

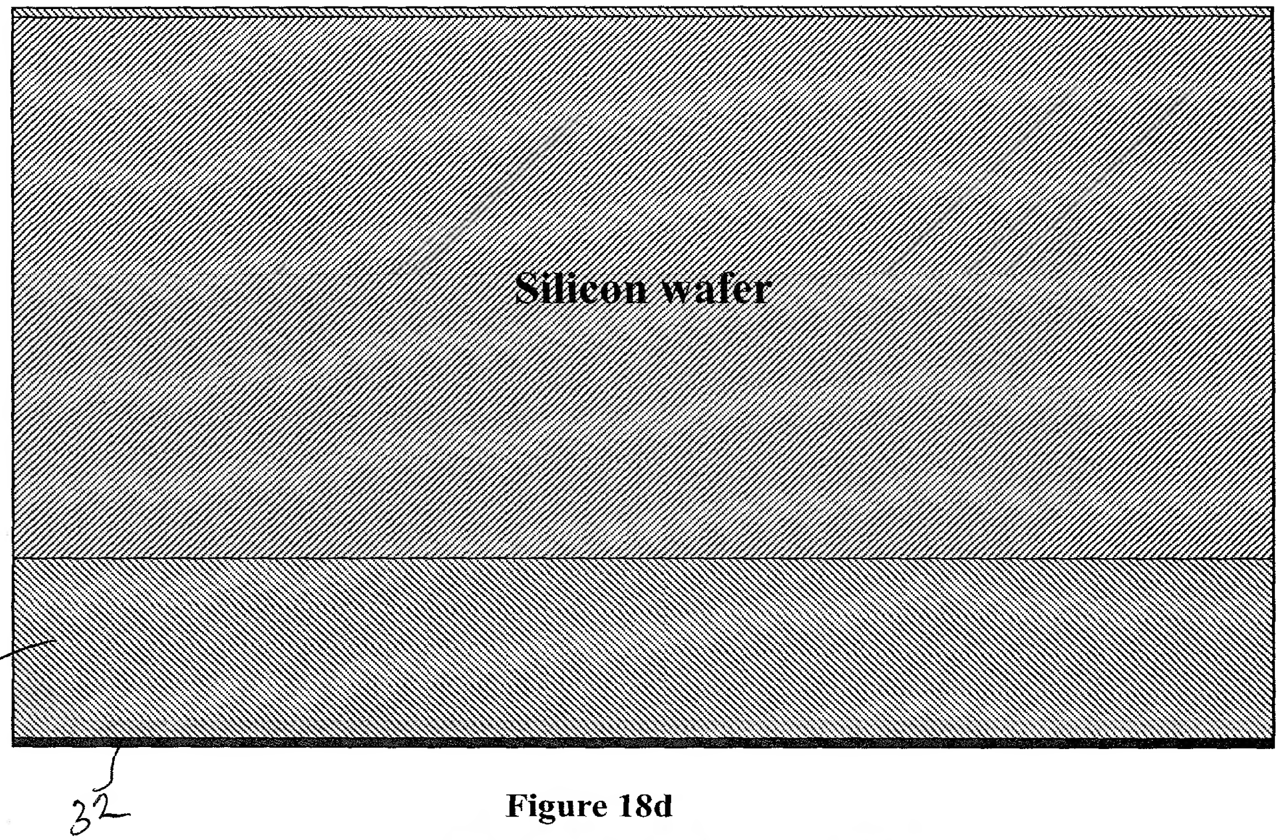


Figure 18d

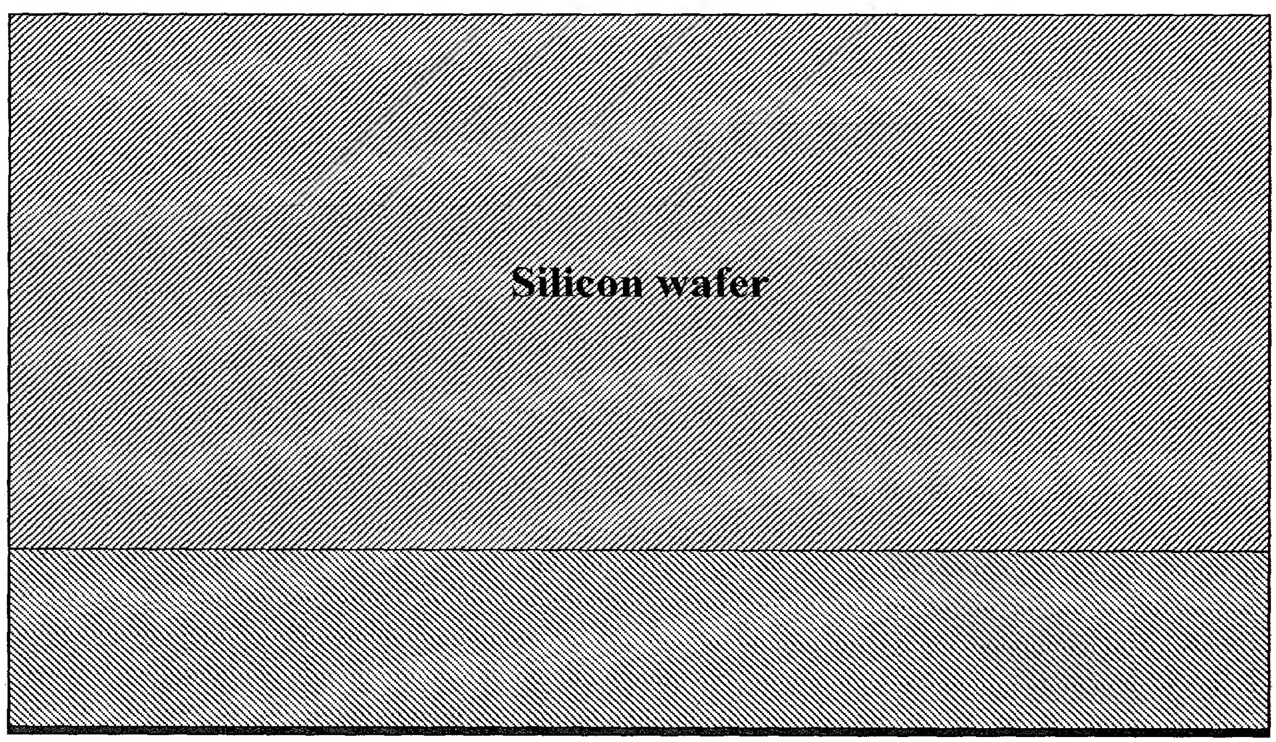


Figure 18e

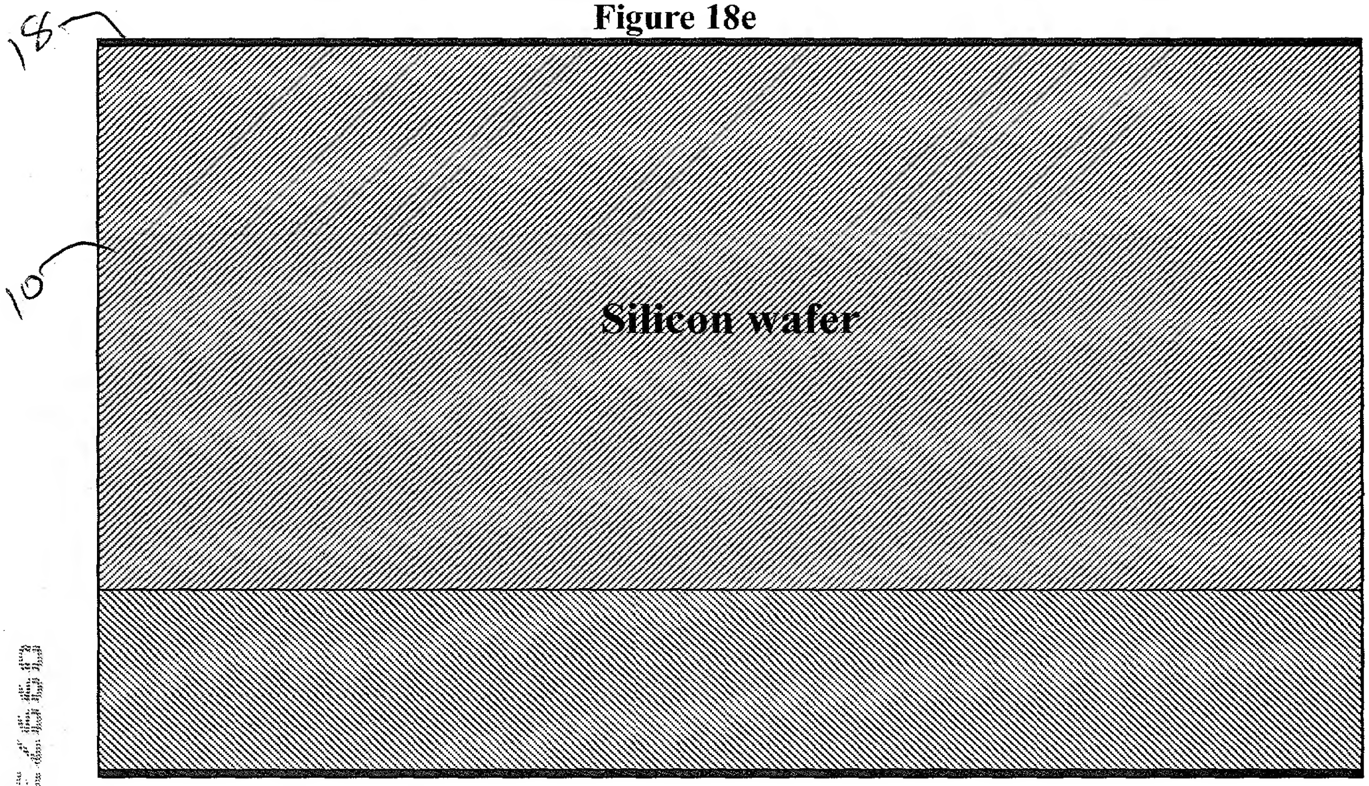


Figure 18f

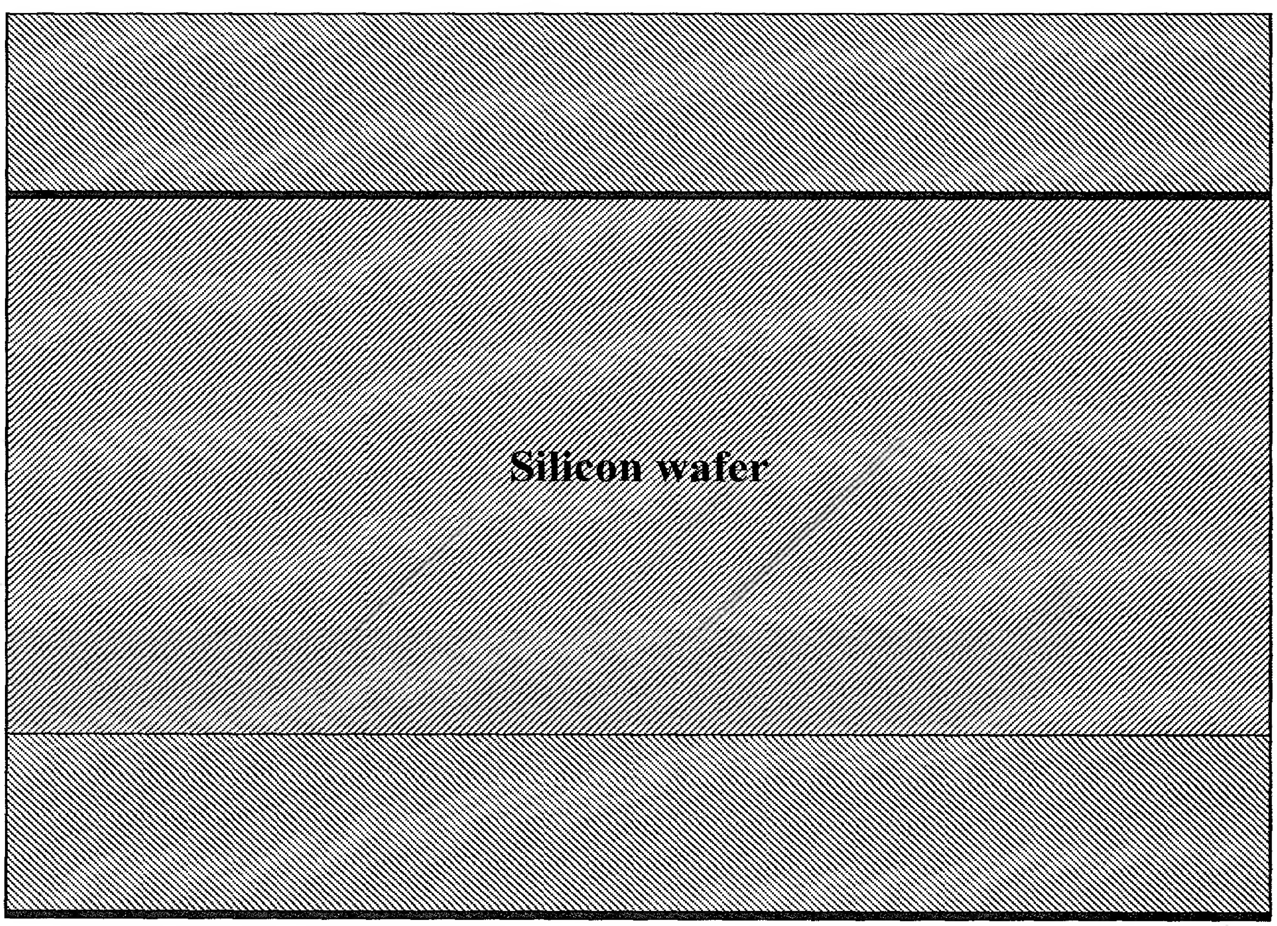


Figure 18g

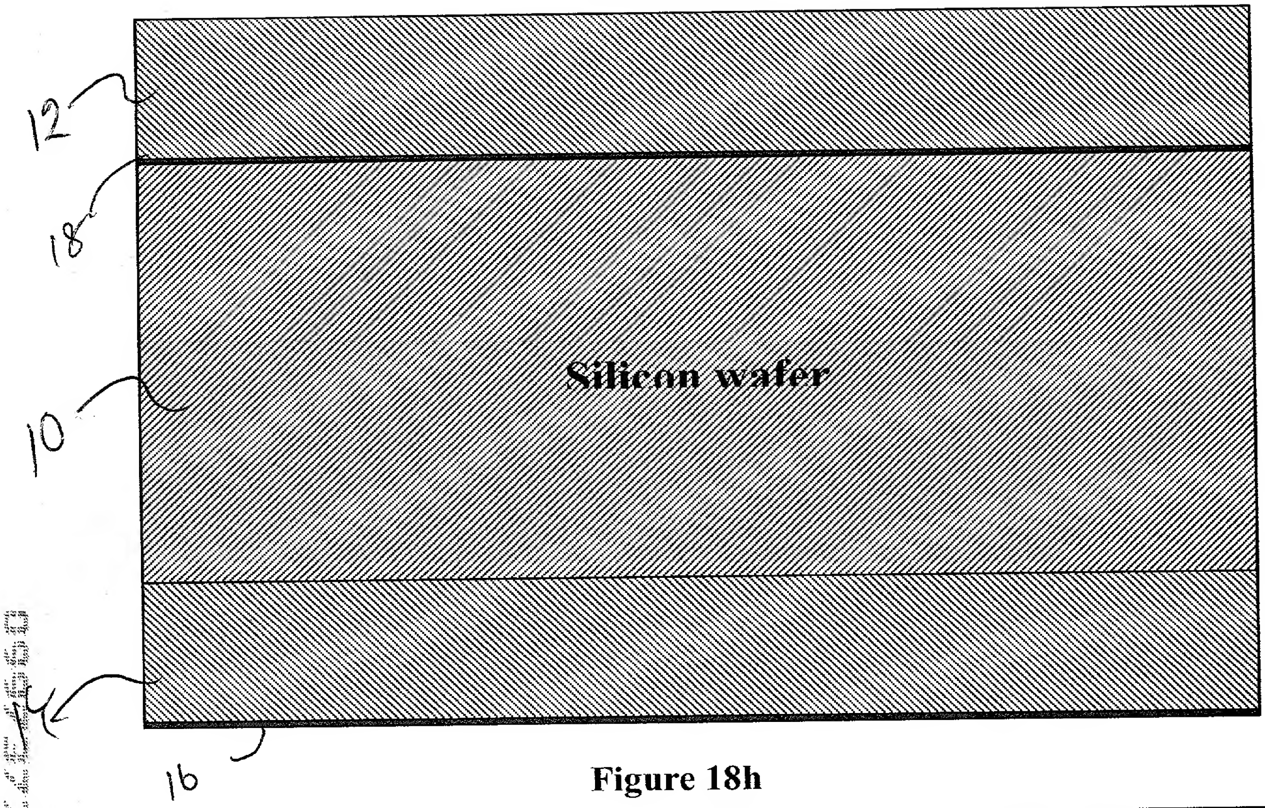


Figure 18h

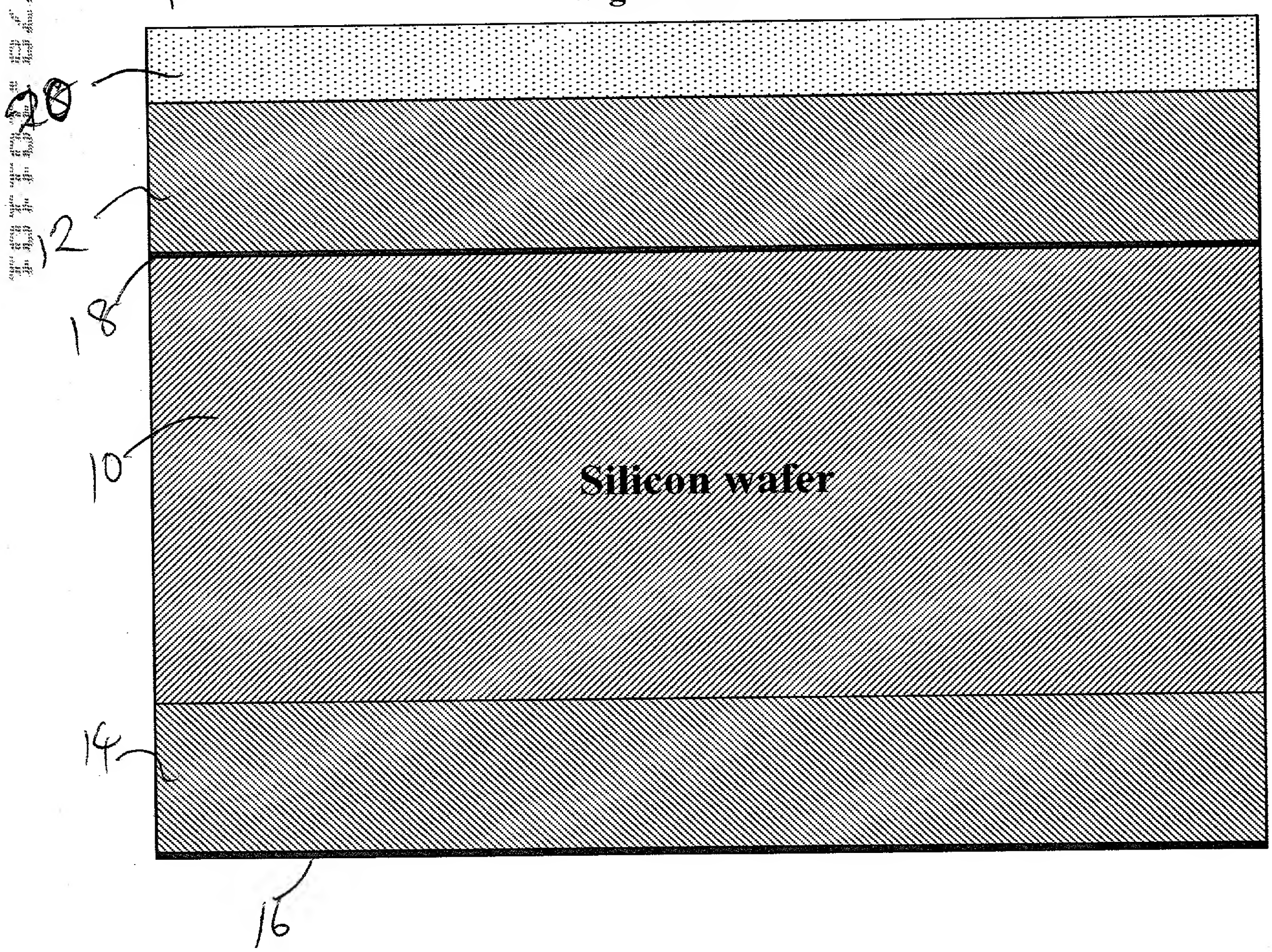


Figure 18i

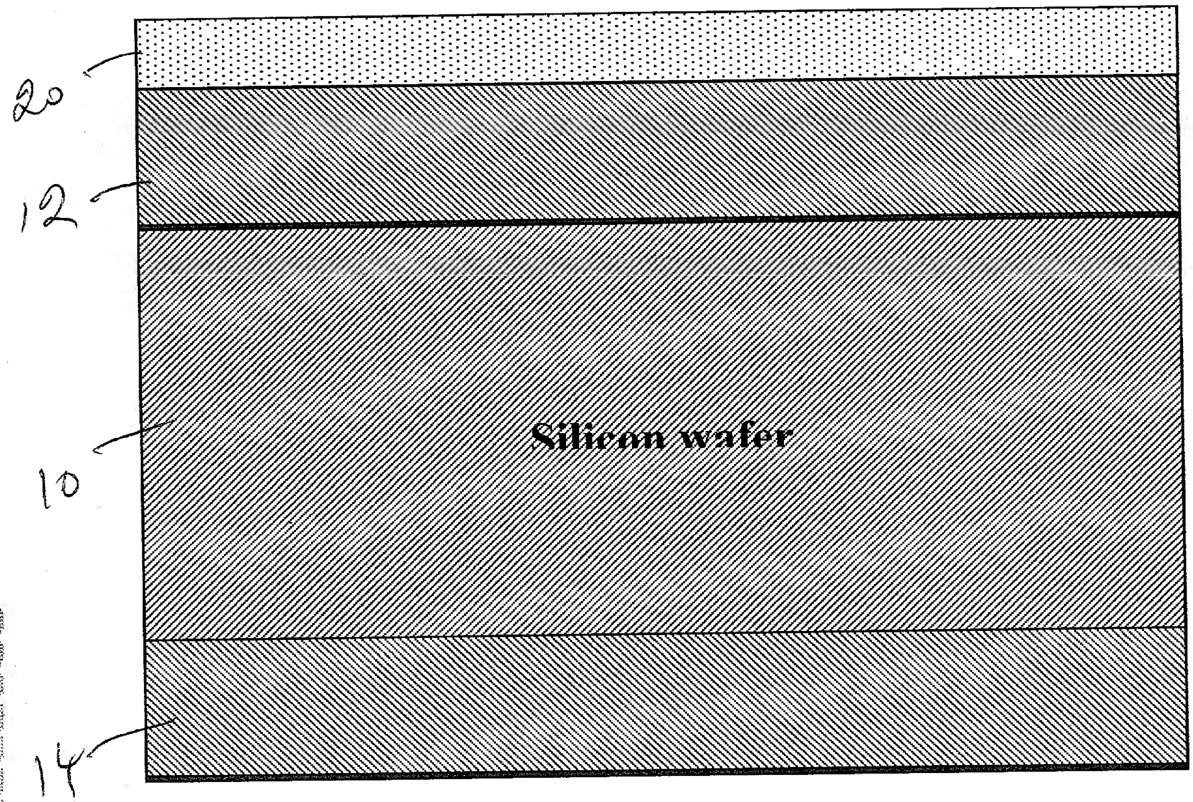


Figure 18j

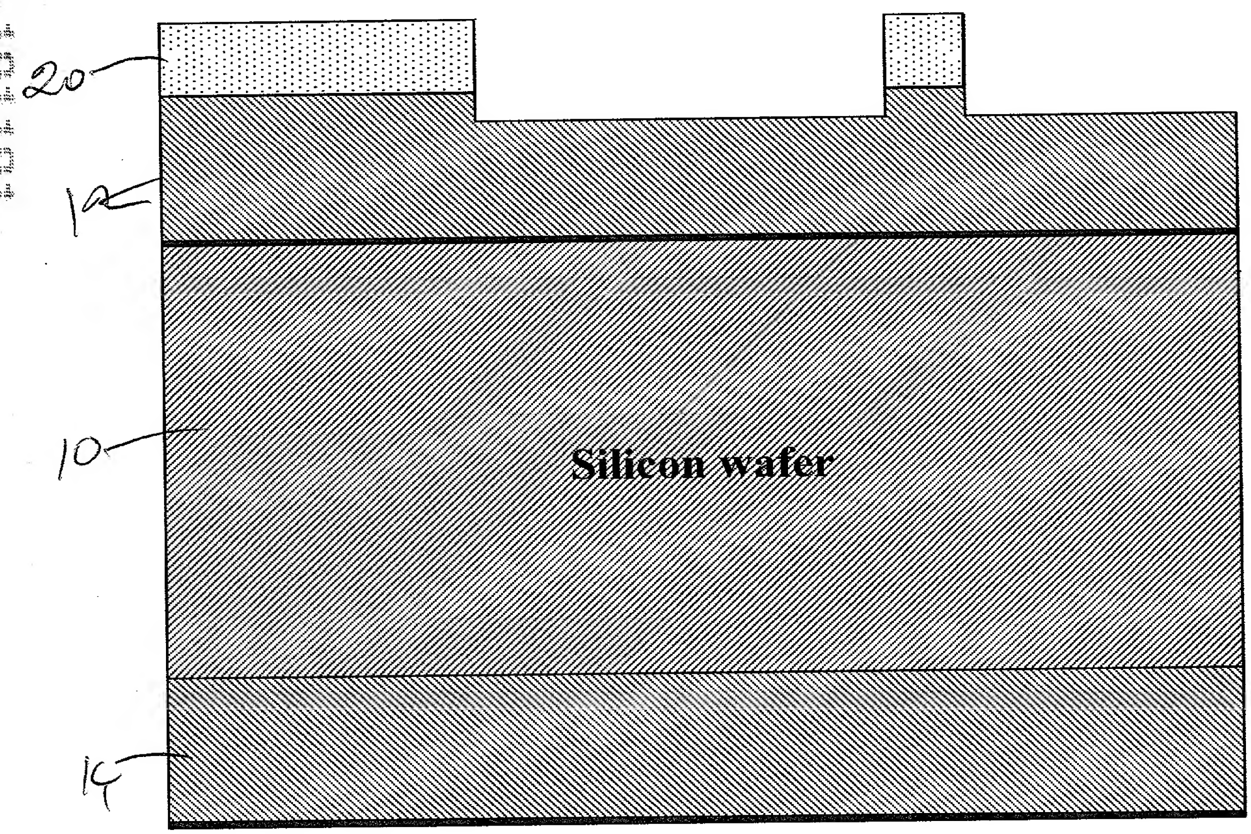


Figure 18k

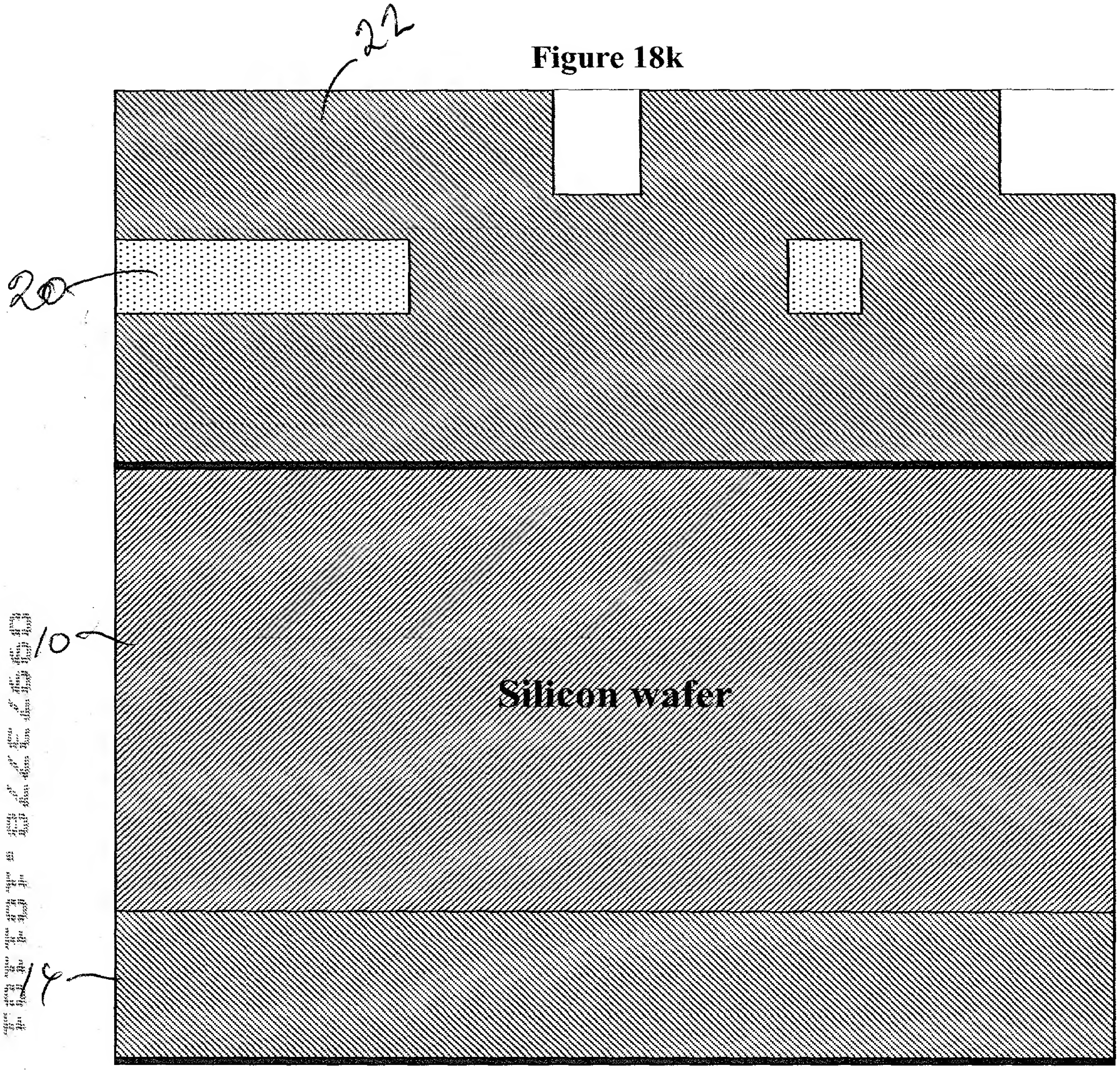


Figure 18l

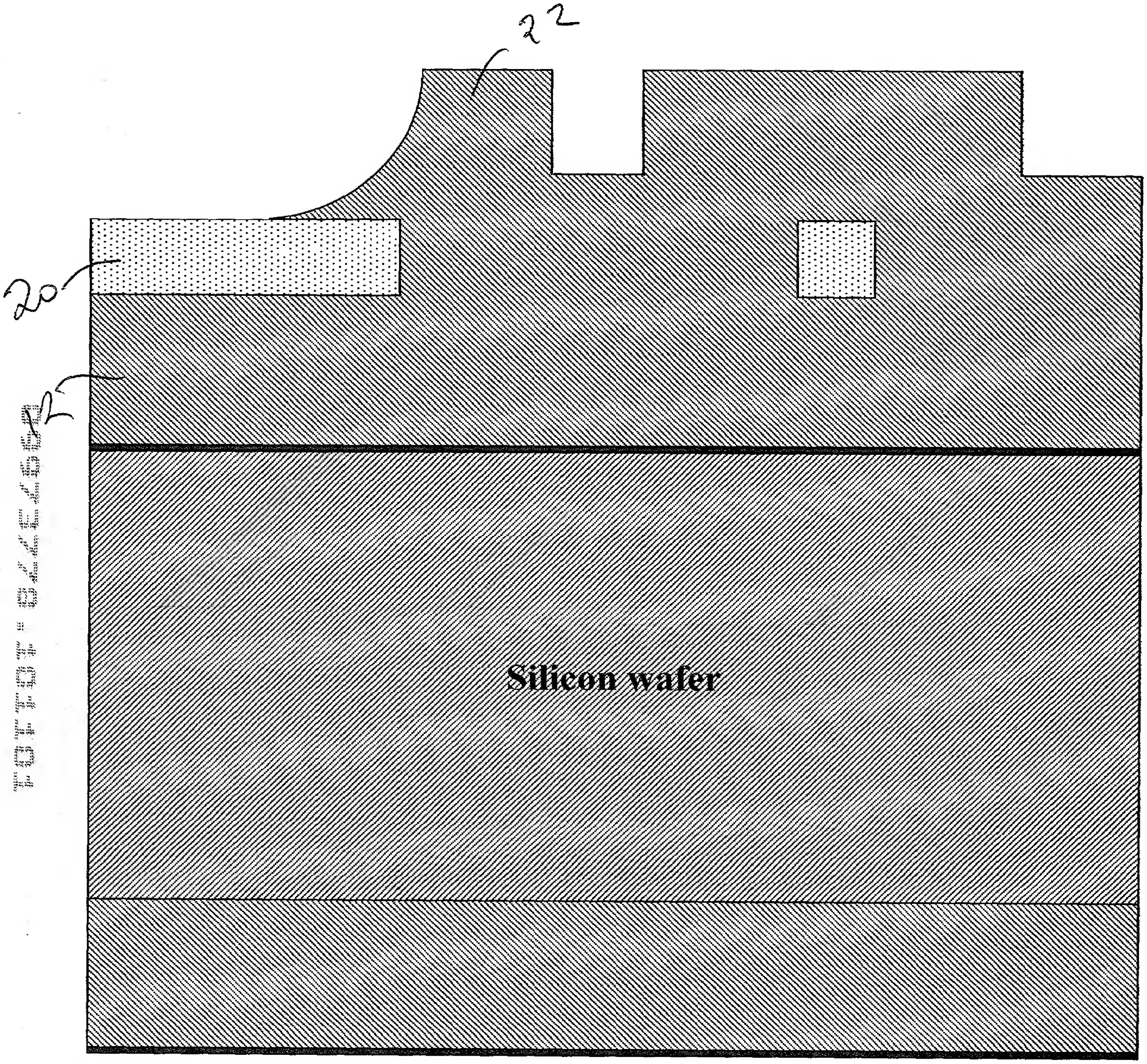


Figure 19

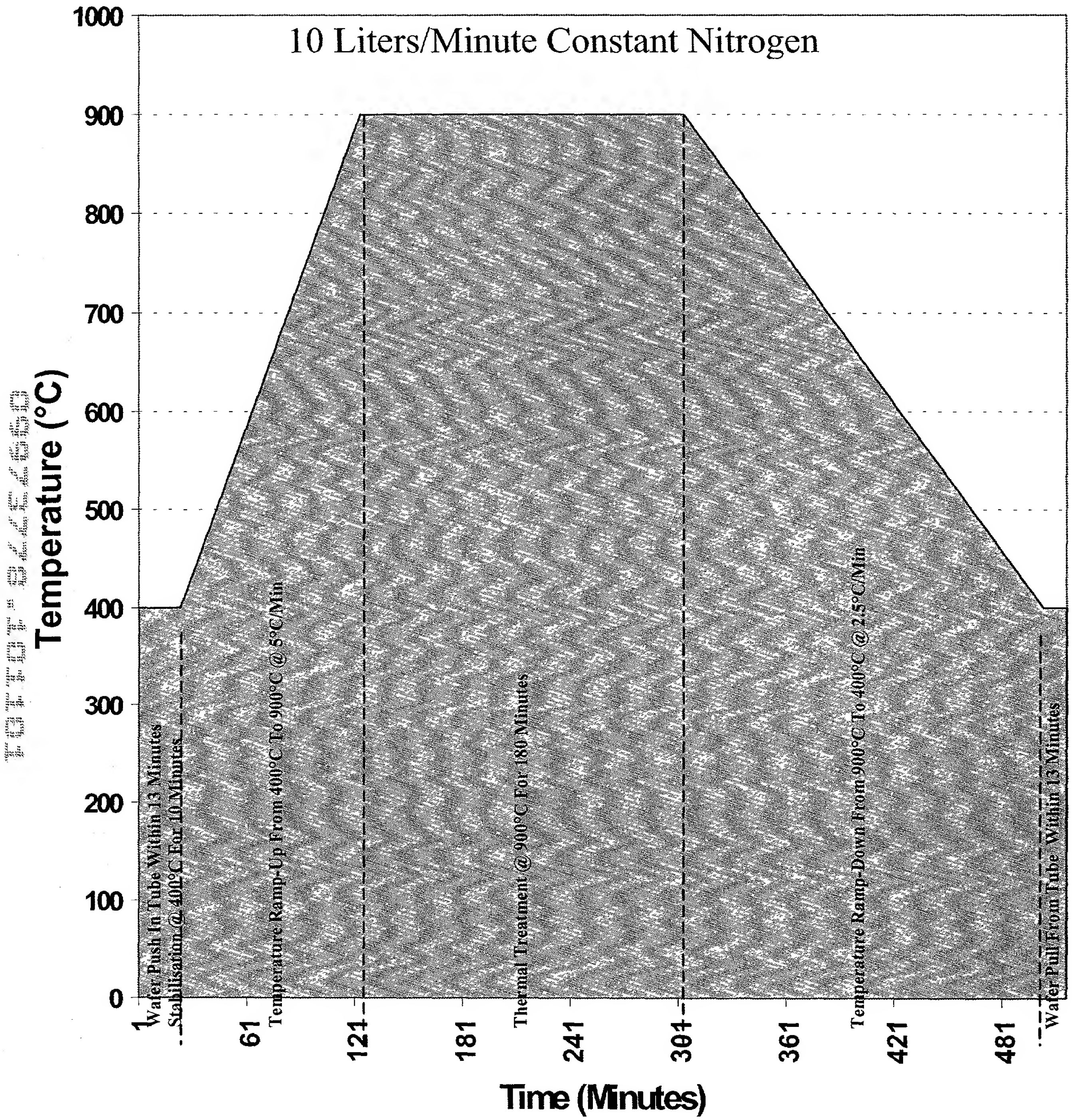
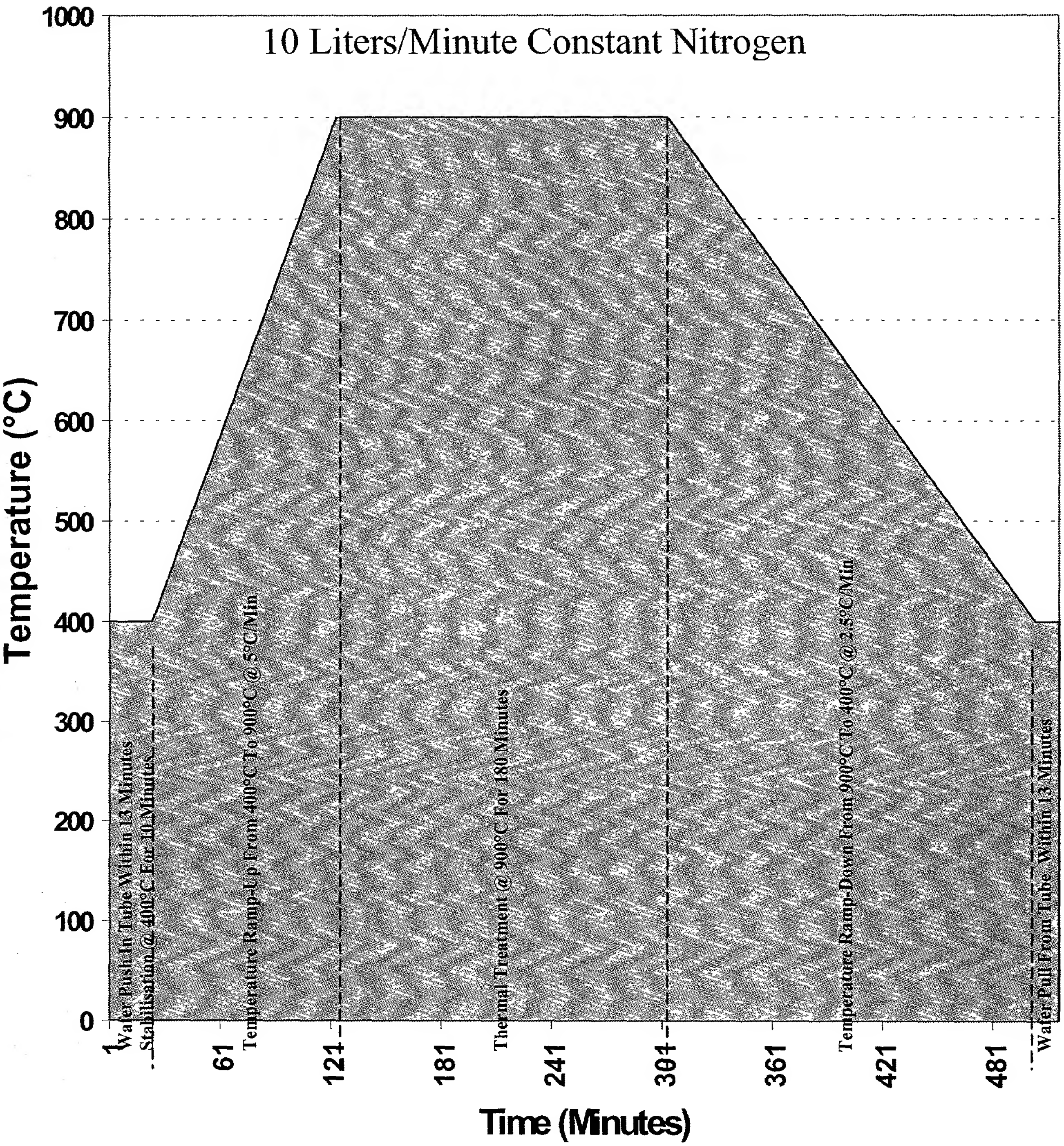

10 Liters/Minute Constant Nitrogen
Temperature (°C)
Time (Minutes)
1000
900
800
700
600
500
400
300
200
100
0
1
61
121
181
241
301
361
421
481
Wafer Push In Tube Within 13 Minutes
Stabilisation @ 400°C For 10 Minutes
Temperature Ramp-Up From 400°C To 900°C @ 5°C/Min
Thermal Treatment @ 900°C For 180 Minutes
Temperature Ramp-Down From 900°C To 400°C @ 2.5°C/Min
Wafer Pull From Tube Within 13 Minutes

Figure 20



10 Liters/Minute Constant Nitrogen
Temperature (°C)
Time (Minutes)
1000
900
800
700
600
500
400
300
200
100
0
1
61
121
181
241
301
361
421
481
Wafer Push In Tube Within 13 Minutes
Stabilisation @ 400°C For 10 Minutes
Temperature Ramp-Up From 400°C To 900°C @ 5°C/Min
Thermal Treatment @ 900°C For 180 Minutes
Temperature Ramp-Down From 900°C To 400°C @ 2.5°C/Min
Wafer Pull From Tube Within 13 Minutes

Figure 21

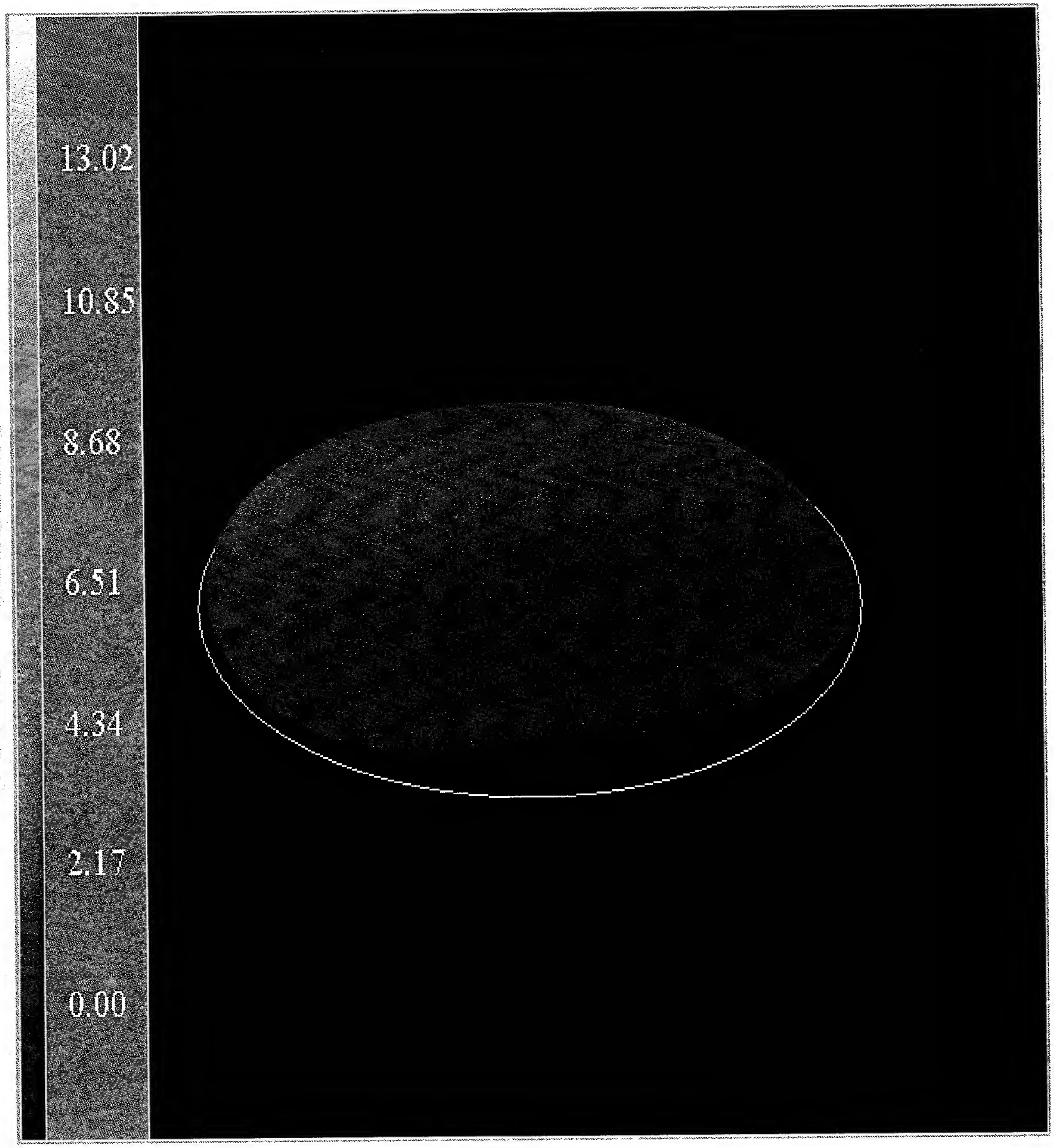


Figure 22

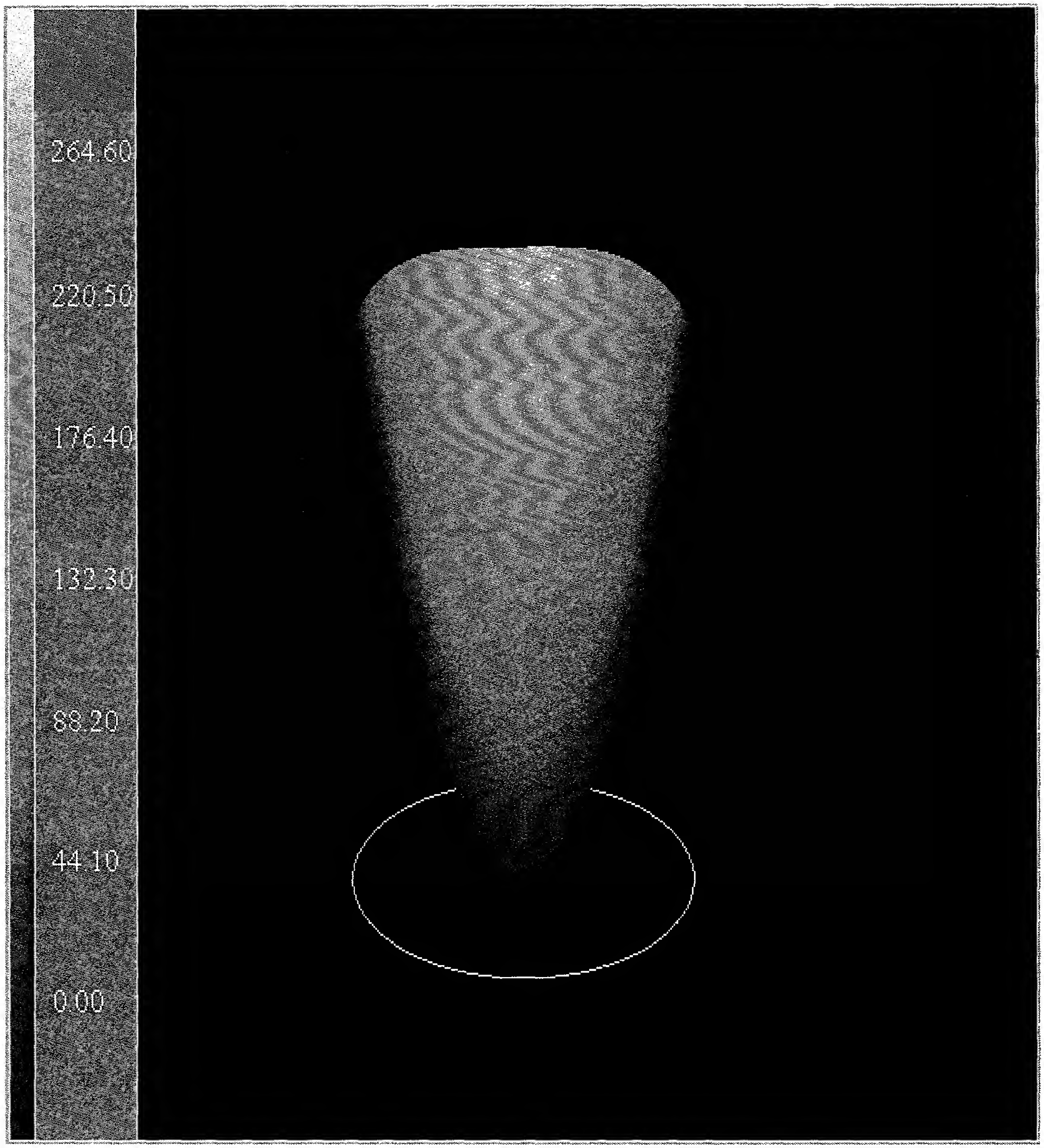


Figure 23